Creating a Multi-modal Transit Corridor

Eastern Province, Saudi Arabia

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I am grateful for my colleagues, friends, roommate, and for sure my family about their support, encouragement, and advice for the last three years. I would like to thank Saudi Railway Organization for their support and research that gave me a foundation for my research. In addition, thank to the Royal Commission of Jubail for their support and encouragement in order to develop Jubail City. Finally, I would like to thank my colleague Eng. Abdulrahman Alsyel for his support and data that he provided for me.

This research is dedicated to my parents, my siblings, and my future wife!

ABSTRACT

The aim of this research is to address the lack of transportation and connectivity in the Eastern province of Saudi Arabia. The industrial field is the biggest investment for Saudi Arabia, and the number of commuting industrial employees has become an enormous burden on the infrastructure system. Jubail Industrial city is located in an expanding and dynamic area and contains experts, companies and colleges focusing on the industrial sector, but it is suffering from the tremendous number of mobility issues for commuters. More than 45,000 employees and students commute daily to Jubail City from Dammam, Qatif, and Ras-Al Khair, and they face many problems on their way such as traffic, accidents, and pollution. Thus, this project will address these issues, and provide a regional plan containing a multi-modal transportation corridor connected with urban hubs between Jubail and Dammam.

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INTRODUCTION

http://riyadh-metro.com

"We strongly believe that transit is a critical means of addressing congestion and driving economic development in many areas around the country...every $10 million in capital investment in public transportation yields $30 million in increased business sales."

JANET F. KAVINOKY, EXECUTIVE DIRECTOR OF TRANSPORTATION & INFRASTRCUTURE, U.S. CHAMBER OF COMMERCE

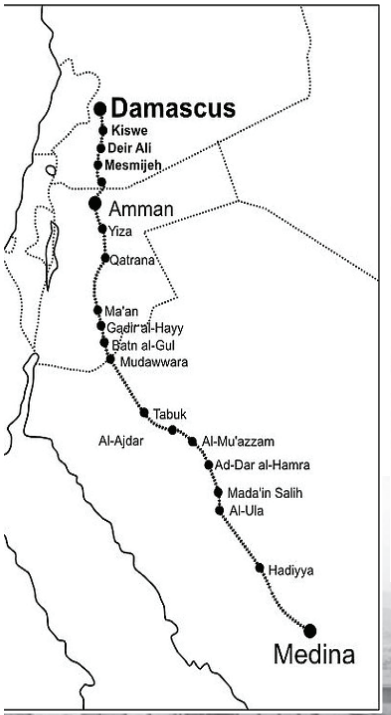
INTRODUCTION

Saudi Arabia's accident rate is six times higher than other Middle Eastern countries because of the lack of public transportation and awareness. Saudi Arabia is the largest oil extruding country in the world, and the Eastern Province is the most significant industrial business zone, which attracts many international companies. Dammam is the largest city in the Eastern Province, and Jubail Industrial City had been cited in the Guinness Book as the largest industrial cluster in the world (rcjy). Nowadays, Jubail City faces many transportation problems such as traffic congestion, pollution, and lack of public transportation, and vegetation buffer between Dammam and Jubail, and there are large number of employees and students who commute to their work everyday. Therefore, adding alternative transportation modes for the eastern province would help solve many public problems, save time and create opportunities for future development.

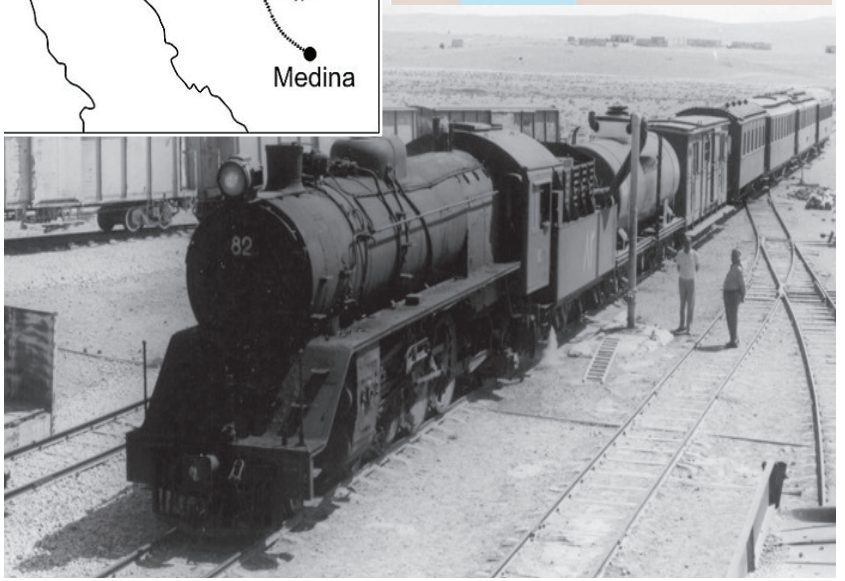
Moreover, by using multi-modal transportation, the trade between eastern cities could be more efficient and enhance socio-culture, environment, and renewable energy issues. Specifically, by linking Jubail city with its neighbors using multi-modal of transits connected with urban hubs and accessible to the shoreline. Each city will have several hubs containing transit stations and public facilities, depending on the context and architectural style of the city. The multimodal transit can be linked with inter-modal transit among Dammam-Jubail Highway, and this will mitigate transportation and environmental problems. Furthermore, this multi-modal transit corridor will be linked with the future plan of the GCC railways, which will connect all gulf countries together. There are many opportunities for the Eastern province because GCC railway will pass through it and create urban hubs that can attract people who will travel from another country by exploring Saudis culture and amenities.

HISTORY OF TRANSPORTATION IN SAUDI ARABIA

http://www.saudirailways.org/portal/page/portal/PRTS/root



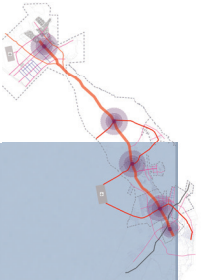
Saudi Railways (SRO) is the company in charge of all railway projects in Saudi Arabia. SRO constructed 1018 km of freight that connects the capital Riyadh with port of Dammam on the Arabian Gulf.



History of Transportation in Saudi Arabia (Hejaz Railway) Before the World War I, Hejaz Railway was constructed to connect north of the Arabian Peninsula and the Islamic Holy cities. This railway route had significant historical and trades places, which provide amenities for the visitors. Currently, the Saudi Government developed the station building and keeps the railway's route as one of the historical places to visit in Saudi. The Saudi Railways Organization has constructed Alharamin Metro, which continues the same idea of connecting the two holy mosques and it will be connected to other countries in future.

Orbaşli, Aylin, and Simon Woodward. 2008.

The focus area is located on Dammam-Jubail highway, with 92km (57mi.) There are several hubs that will connect the corridor with the small cities such as Qatif, Tarot, and Ras Tanoura. The corridor will pass by residential, industrial, agricultural, and historical zones.



Jubail Industrial City is located on the Arabian Gulf, 100 kilometers north of the
Dammam metropolitan area.
This unique location gives it two major advantages; accessibility to international sea-lanes through the Gulf and proximity to sources of energy and raw materials for refining and petrochemical production.

Current issues along this highway include:

-Lack of public transportation

-Serious risk of accidents – the injuries ratio per accident in Saudi is 6 times higher than the international ratio (Gareth James 2014)

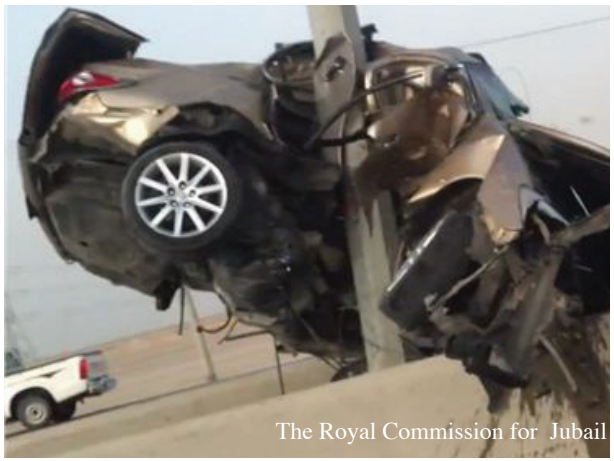
-Pollution and desertification

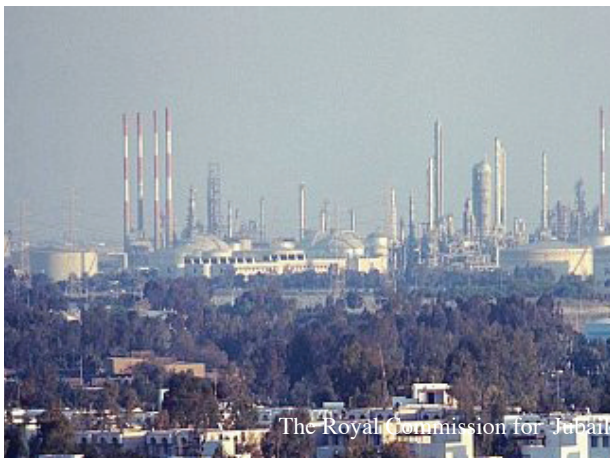
-There are more than 45,000 employees commute to Jubail everyday Dhahran, Dammam, Qatif, and Ras Tanoura (RCJY.)

-86% percent of Saudis use cars as a main type of transit.

-More the 60% of accidents occur on highways outside the city limit (Moi.gov.sa.)

-According to the Kingdom's General Directorate of Traffic, more than 17 Saudi residents die daily due vehicles accidents


The Royal Commission for Jubail


The Royal Commission for Jubail

Research Questions

- Where should public transportation and urban hubs be connected to provide significant hubs for the residents at the Eastern Region of Saudi Arabia?
- How can we provide safe and satisfying amenities for residents, visitors, and employees who commute daily to their work?

Research Goals and Objectives

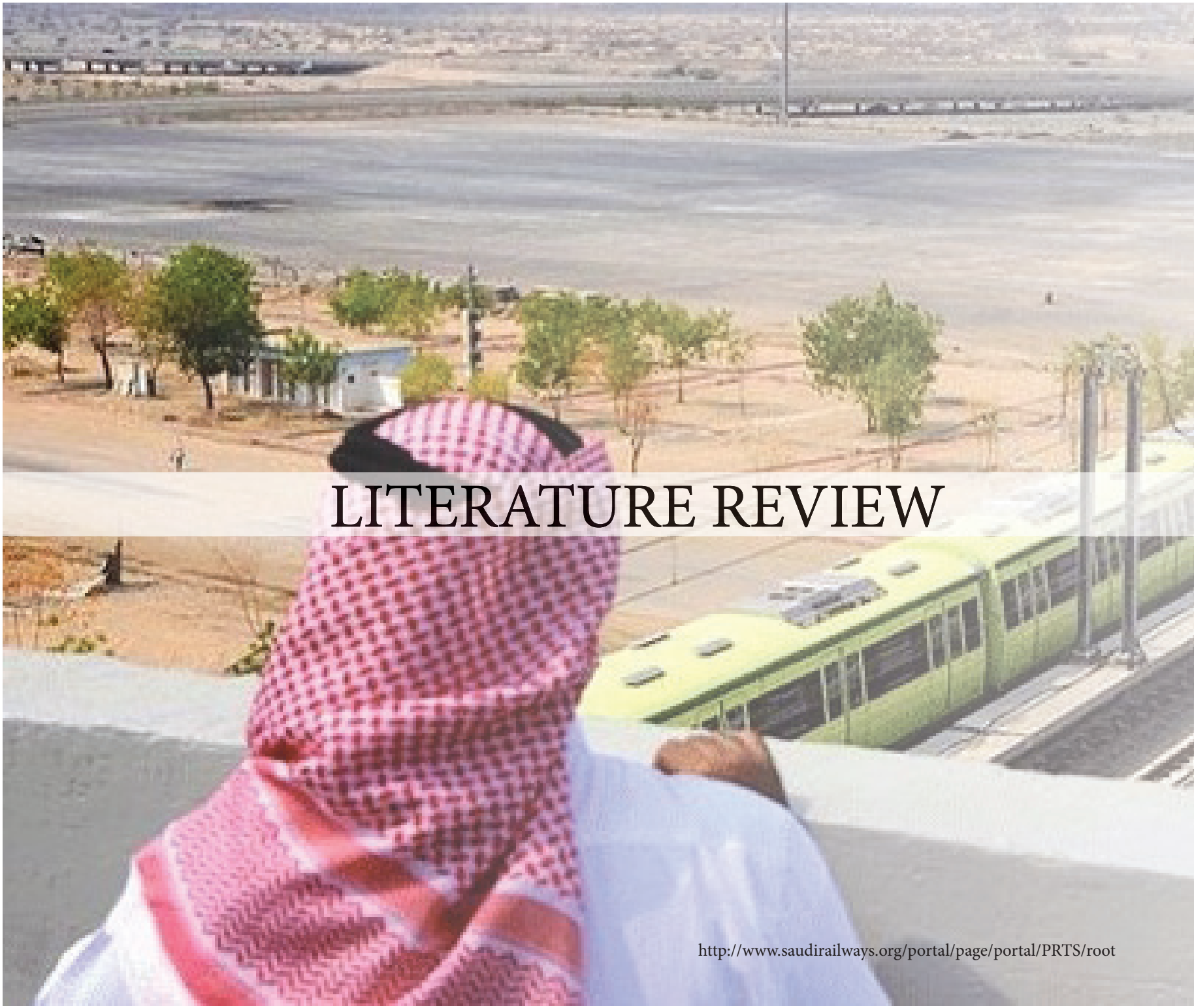
1. Design a multi-modal transport corridor connecting Dammam metropolitan with Jubail industrial city.

   Objective. The corridor will contain a light rail, bicycles, and cars connected with several stations, which will provide urban hubs to focus walkability – related issues.

2. Decrease pollution and environmental impacts.

   Objective. Design a solar panels system and wind turbine along the corridor, which will be used to run the light rail and stations. Increase the vegetation buffer, and water harvesting to mitigate erosion issues.

LITERATURE REVIEW



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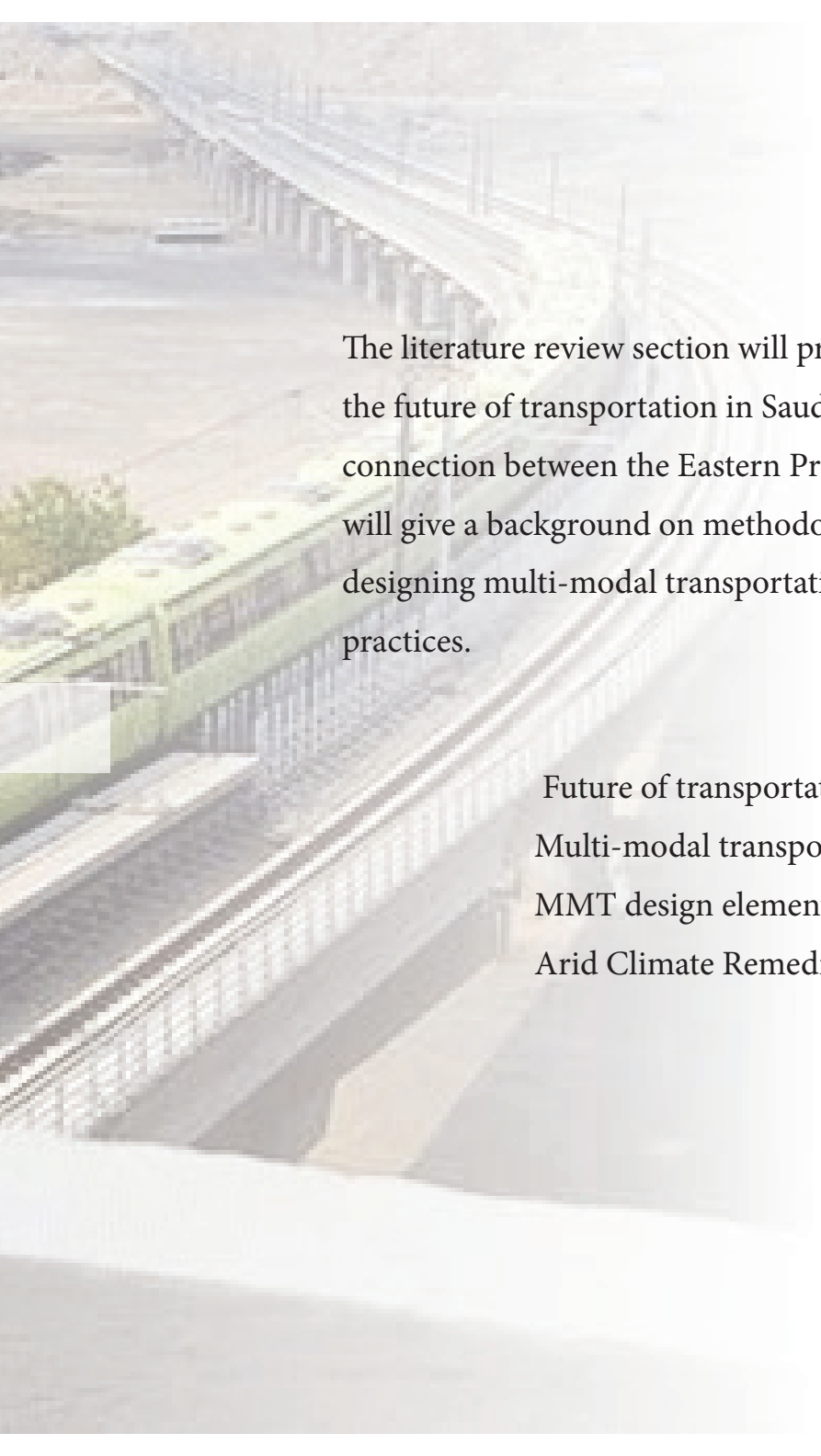
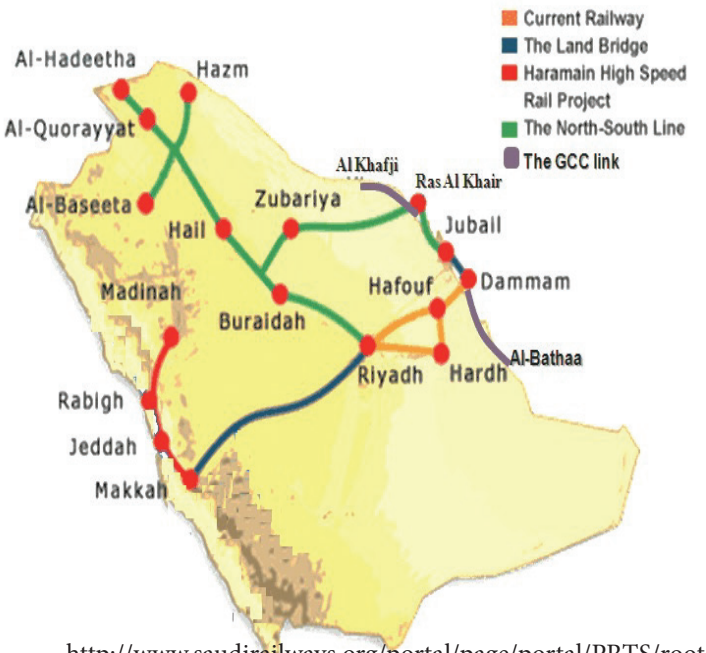


The literature review section will provide an overview of topics related to the future of transportation in Saudi Arabia, and how to propose a reliable connection between the Eastern Province cities. These topics listed below will give a background on methodologies that will be used as criteria for designing multi-modal transportation corridor and promoting sustainable practices.

Future of transportation in Saudi Arabia
Multi-modal transportation and urban hubs
MMT design elements and urban consideration
Arid Climate Remediation

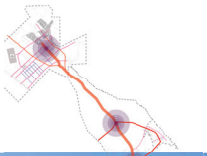
FUTURE OF TRANSPORTATION IN SAUDI ARABIA

Saudi Arabia is one of the largest countries in the Middle East with similar size of Western Europe. The distance from the east coast to west coast of Saudi is approximately 1,350 km (838.85mi), and from the south border to north of Saudi almost 1,789km (1,111mi). Therefore, Saudi Railways Organization has proposed some alternatives in the field of railway transport, which will enhance the connectivity between the largest cities in Saudi Arabia. Also, Saudi Railways Organization developed a master plan for the transportation in Saudi between 2010-2040, and this plan provides 19 different lines that will be accomplished in three phases. This master plan is one of the National Transport Strategies (NTS), and this strategy contains six main goals for designing a railway related to efficiency, social and economic development, safety, environment, security, and Hajj Transportation (SRO).



http://www.saudirailways.org/portal/page/portal/PRTS/root

In addition, the master plan of the Saudi Railways organization provides a new transit evolution for the Gulf Cooperation Council (GCC), where all the gulf countries are going to be linked by a railway. The total distance of this route is 2,177km (1.352mi) and will start from Kuwait city south to the Sultanate of Oman, and it will cross Jubail Industrial city, Dammam city, Hofuf, UAE, and final distension Muscat, Oman. Dammam already has a route to Riyadh and Hofuf, and the future plan will link Dammam with Bahrain and Qatar by a new causeway connected with the King Fahad Causeway. This project will enhance the multi transportation corridor between Dammam and Jubail, an industrial city, because many tourists will pass through this multi-modal corridor.



Recently, Saudi Arabia transportation routes have dramatically increased, which will affect and help development of the environmental, economical, and the socio-cultural factors of the area. Moreover, modern transportation has significant affect in energy and environment.

The capital of Saudi Arabia, Riyadh has undertaken a new transport theme "Riyadh Metro," which will connect King Abdullah Economy city with the neighbors (SRO).

Riyadh is expanding in growth fast and this expansion requires satisfactory transportation, which will decrease the congestion of traffic (mot). The metro route is 178km (110.6mi) with six lines and eighty-five stations, divided underground, and elevated.

In addition, the western coast of Saudi Arabia has also undertaken two large projects undertaken, Alharameen metro, and Alamshaaer metro. Both projects aim to serve visitors, who are coming to visit the two holy mosques. These projects will serve Jeddah, Makkah, and Madinah as well.

Aloulya Station, Riyadh, KSA (Riyadh Metro)

Future of transportation in Jubail industrial city

The Royal Commission of Jubail and Yanbu has undertaken multifaceted master plan for Jubail city called "Jubail City Center." The approximate area is 200 hectare divided between: city center for business, living, and entertainment. This master plan will develop the economy of Jubail, by attracting industrial companies and employees to start thinking about this modern and desirable place. Also, the vision of the Royal Commission is to provide alternative energy sources such as solar, wind, and water.

Jubail City Center will provide a unique and satisfying environment for its employees, where the transportation, community service, and entertainment facilities are connected within their workplace. The approximate population for Jubail in 2040 will be increased more than half because of the business activities, affordable housing and public amenities (rcjy).

Ras-Alkhair and Jubail Transportation Link Study


James, G. (2014)


James, G. (2014)

Halcrow Company proposed a master plan to link Jubail industrial city with Ras-Alkhair industrial city, which will contain different types of transportations such as car, coach, rail, and marine. The distance between Jubail and Ras-Alkhair is about 200km, and the commuter employee will dramatically increase between 2020-2040 (James, 2014.)

The master plan will provide several pick up points for the employees from city center to their plants by using coach and rail. Marine is an alternative option for the employee, where they can move faster from Jubail to Ras-Alkhair connected with coastal hubs.

The RIC-JIC Link study had been examining different strategies to accomplish the best option for this link. The multi-modal strategy is the recommended strategy for the RIC-JIC link for several reasons; fewer accidents, fewer risks, more environmental benefits, comfort, and reduced congestion.

What is MMT?

A multi-modal transportation (MMT) is an area that contains a mixed use of transport for people, and provides safer and attractive alternatives for environment and pedestrian. Multimodal design can increase the uses of mobility, which will provide significant connections between environment and community (AICP 2004). As the graphic to the right the Multi-modal Transit Corridor is defined as walkable nodes on the corridor surrounded by the rail stations. Those stations can be connected with different type of transit such as heavy or light rail, streetcar, and bus linked with urban hubs (TOD). Moreover, urban hubs can provide multi use plazas, which serve the community and the public by increasing the size of promenade and walkability.

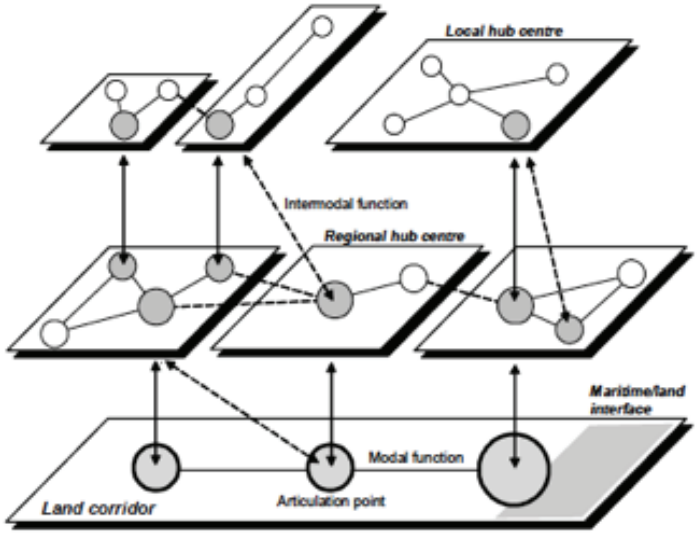
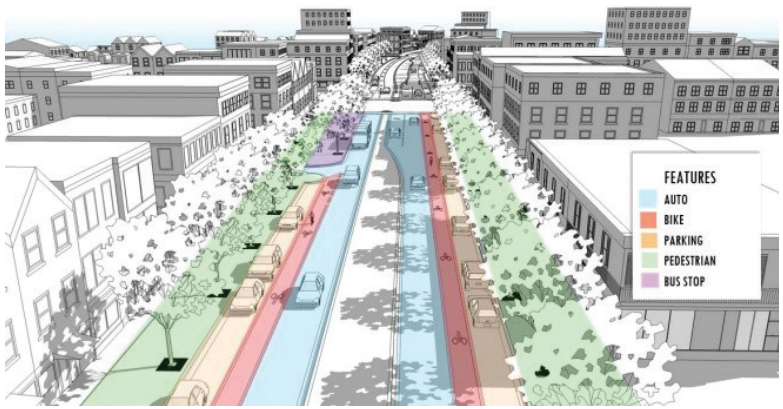


Figure 2 Multimodal Transportation in Corridors

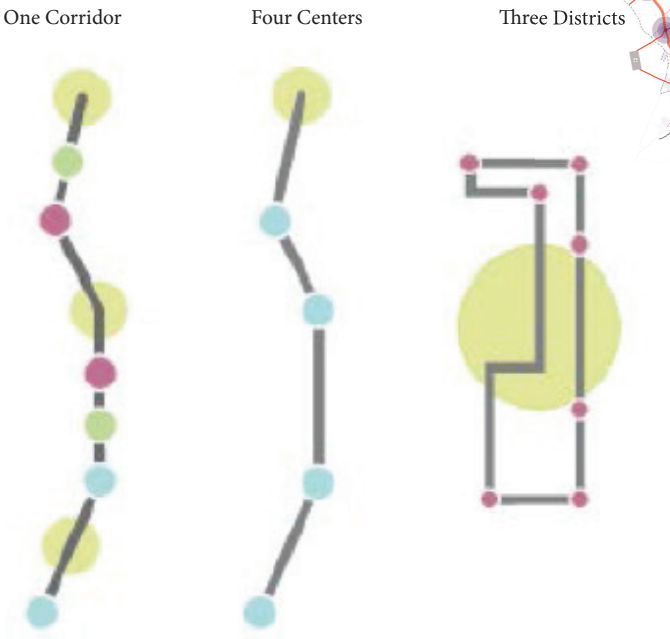
(AICP 2004).



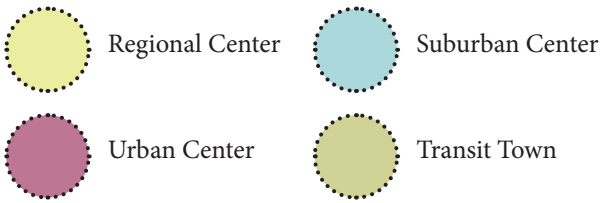
Forms of MMT

Multi-modal transportation has several forms regarding to its context, for instance, urban center, regional center, or traditional town/village (AICP 2004). In addition, there are three basic corridors types; destination connector, commuter, and district circulation (TOD).

In transit-oriented development, multimodal designs can be described as a corridor, a hub, or a district. A hub includes four centers: regional center, urban center, suburban center, and transit town center. The three districts are urban neighborhood, transit neighborhood, employment district, and special use. The one corridor is a mixed-use corridor (TOD).



(AICP 2004).



Urban center (large city)

This type of MMT is located in a large city and depends on the surrounded activities such as stores, pedestrian, bicycles, and transit. This urban center can be used as a multi-use hub for residential and employees who pass it, and provide different choices for public.

Regional Center (medium city)

This type of MMT is a perfect hub for a small town or city, where people can visit it daily. In other words, an open space in a new town where most of the residents can find all services and amenities within walking distance.

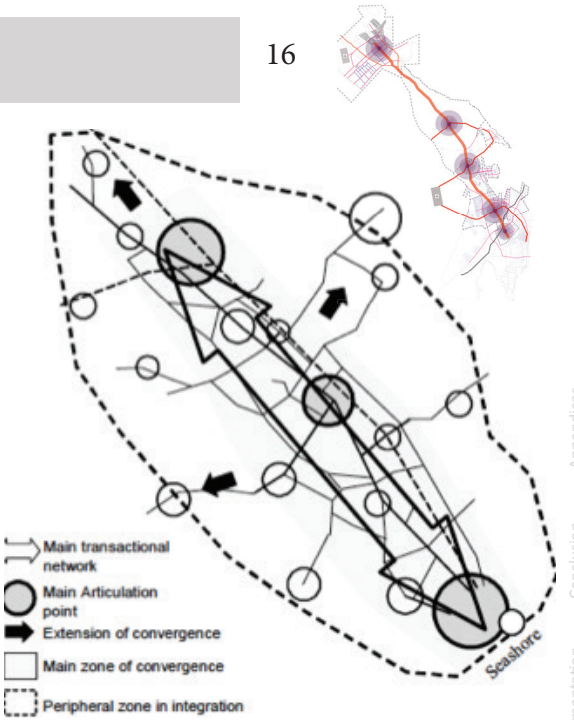
Traditional Town/Village (small city)

This type of MMT can be assigned to old town or district and respect the theme and sense of the community. Usually it connected by major streets or transit.

(AICP 2004).

Spatial Convergence in Corridors

The entire multi-modal transit corridor should be connected with arterial corridors by having well-designed criteria. Safety is the most important issue between the different transits, especially between bicycles and other major transits. Also, pedestrian should have clear and safe accessibility, which will lead them to the amenities and transit locations. The public activities should not intersect with the transportation lanes in order to avoid any accidents. Major transport must have a clear and adequate connection with the minor transportation, which will provide transition areas for pedestrian connected with amenities (AICP).



(AICP 2004).

The evaluations of "inter-modal passengers transfer facility," by Horowitz and Thompson place emphasize on security, safety, and easy movements along the corridor being the necessary design criteria for the urban hubs. The convergence hubs will link the socio-culture, economy, and environment. Therefore, they must contain transition and articulation areas between different activities, such as mobility, accessibility, walkability, and promenade, which will imply the connectivity between the corridor and its contexts.

Design elements of MMT should consider the following:

A. Well-developed communications between streets, mobility, bicycles, pedestrian, and walkways, which will support walkability from and to the urban hub.

B. Integrate the land use with the function of the urban hub such as socio-cultural, recreational, and educational.

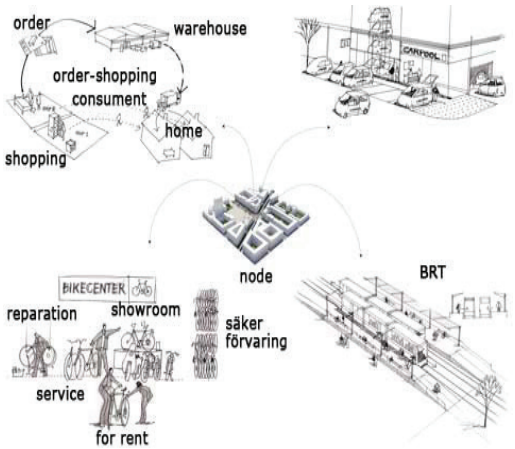
C. Provide safe and satisfy plaza for residences and their visitor.

Urban consideration

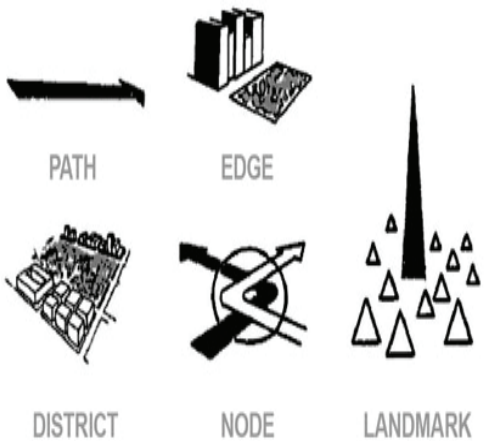
Urban design is influenced by society; it can reflect the culture and theme of any place, and moving elements and stationary physical parts can be the most effective elements on the people's city image (Lynch, 1960.)

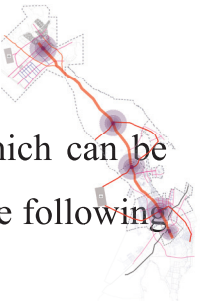
Each society must have a responsive environment and can be defined with these characteristics; permeability, variety, legibility, robustness, visual appropriateness, richness, and personalization. By achieving all these criteria, the urban form of the society will be a well responsive environment (Kevin Lynch).

Nodes can be defined as anchor points, where surrounded features can be defined as as topography, vegetation, buildings, roads, and sky. There are several criteria to indicate the urban nodes for instance, providing strong and continuous axis, providing some landmarks, simplicity of designing the general theme, and permeable circulation between the functions.



(Lynch, 1960.)





The United of Arab Emirates provides a public realm design manual for Abu-Dhabi city, which can be used to design in an arid zone (Abu Dhabi Public Realm Design Manual, 2007.) It highlights the following characteristics:

Quantity: number of stop stations (urban hubs)

Proximity: location of the hubs within the cities

Accessibility: easy access to the hubs from any type of transportation and context

Distribution: make sure that's every modal of transportation and pedestrian can interact and cross these hubs

Equality: provide appropriate materials and methods related to the arid zones

Coordination: combining stations with the urban hubs and neighborhoods

Balance: provide multiple functions along the corridor

Shaping: provide flexibility for future expands

Connections: link all the towns along the corridor with some rest area and hubs.

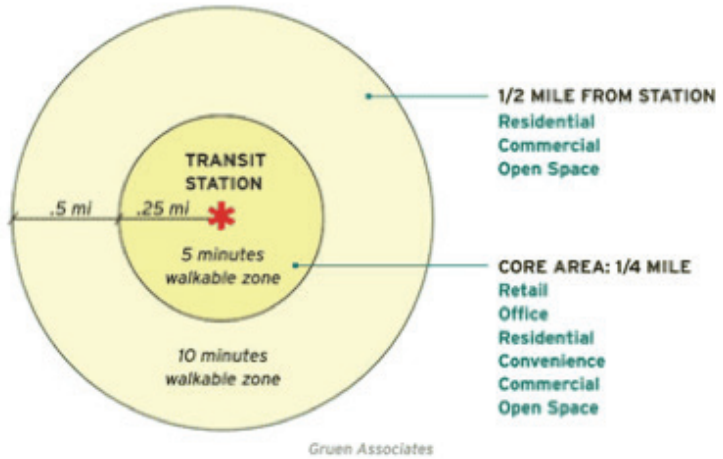
(Abu Dhabi Public Realm Design Manual, 2007.)

(Abu Dhabi Public Realm Design Manual, 2007.)

TOD and Multi-modal Transportation Policies and Guidelines

TOD is an American organization for Transit-Oriented Development, and this concept manages regulation is in charge of the regulation and guidelines regulating for transit and built environment connectivity. There are nine planning principles that TOD considers to design a multi-modal transit corridor;

1. Maximize ridership with transit-oriented development
2. Generate meaningful community involvement
3. Design streets for all users
4. Create opportunities for affordable and accessible living
5. Make great public spaces
6. Manage parking effectively
7. Capture the value of transit
8. Maximize neighborhood and station connectivity
9. Implement the plan and evaluate its success



Transit Oriented Development

General TOD Guidelines for Urban Design

Circulation

- Connected street systems
- Small block size
- Traffic calming
- Appropriate Roadway Standards
- Alleys
- Off-street Trails, Bicycle and Pedestrian Pathways

Site and Building Design

- Street-oriented building placement
- Visible and accessible entries
- Garage treatments
- Architectural variation
- Transparency
- Compatible height, massing and style

Public Space Design Strategies

- Streetscaping
- Civic Plaza at transit station
- Landmark features

Station Design

- Connections to adjacent spaces and buildings
- Station amenities
- Transit station as community landmark
- Parking and Loading Areas

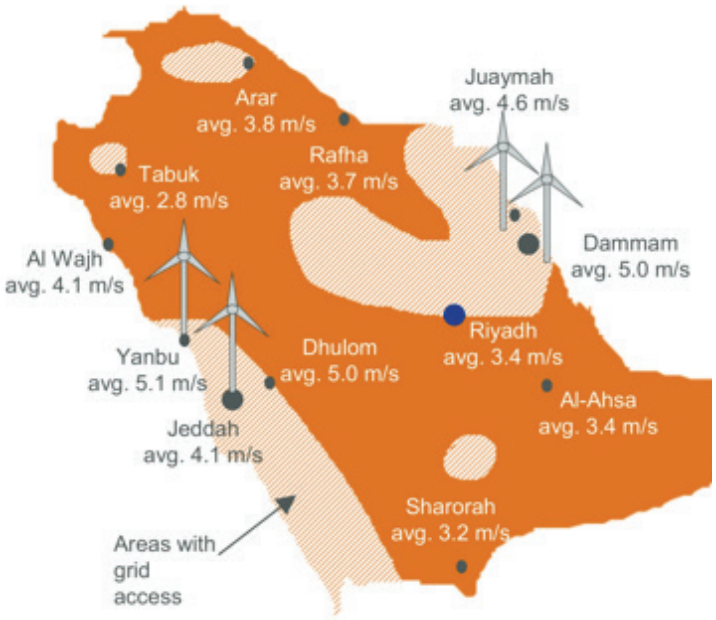
Parking and Transportation Demand Policy

- Parking Maximums and Minimums
- Shared Parking
- District Wide Parking
- Parking Structures and On-Street Parking
- Car Sharing
- Parking Pricing
- Other Transportation Demand Management Strategies

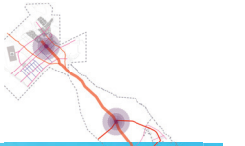
Saudi Arabia is located in an arid zone, where designing a public space indeed requires specific policies and regulation that can provide comfort zones for people. Saudi is suffering from desertification because of the poor management of natural resources. Desertification can destroy the cycle of life, leading to less wildlife, less vegetation, and less rain precipitation. Moreover, lack of rain effect the soil layer and increase its erosion, which will destroy the vegetation (Zahrani, 2011)

Renewable energy in Saudi Arabia

Saudi Arabia is expected to become the largest source of renewable energy in the Gulf area. The Saudi Government realized that oil sources are not dependable, and they should find another renewable energy source to support their investments. The plan will generate approximate 9 GW/S from the wind capacity by 2032, and 1.8 GW/S produced from the solar system capacity. The largest industrial companies will be participating to accomplish this sustainable project. The approximate wind capture investments in Saudi Arabia is 100-200 USD and its will be increase 50% by 2020 (Mayr, 2013)



Source: Eltamaly et al. 2012, Rehman et al. 2003, Apricum analysis. Wind speeds measured at 10 m height.



Largest Man-Made Industrial River

Jubail Industrial City has the largest seawater cooling system in the world. It consists of three huge concrete open-canals reaching 11 km in length. The system is designed so that intake and exhaust flow never mix. Reinforced concrete walls divide intake and return canals. The temperature of the Gulf water is not affected by the cooling operations as return water is cooled by natural methods in order to maintain marine life. These canals were constructed by the Royal Commission and currently run by MARAFIQ Company (RCJY.)

Jubail Industrial City is 102,000 hectares—10 times the area of the Panama Canal. The city now serves 17 primary industries, 21 secondary industries, and 132 support and light manufacturing industries. The industrial development requires the world's largest seawater cooling system to pumping more than 1 million cubic meters per hour (NYTIMES, 2007.)

Human Thermal Comfort concept

Human thermal is generally defined as the best weather temperature and moisture, where human can stay comfortable. The concept focuses on solar radiation, wind, temperature, humidity, and precipitation, where each element has different calculation and consideration to reach the comfort of human thermal.

In the literature review by Robert D. Brown (2010.) He discussed the main concept of the human thermal comfort. Brown thinks that the air temperature and its humidity cannot be changed by the elements of landscape such as vegetation, water, and etc. Also, he considers the sun as the main source of heating in any open space, using reliable and sustainable landscape elements can change the heat to useful energy sources.

Although, wind is one of the weather moderators, and it can ventilate the landscape elements and replace heat of the solar radiation during summer. By using the landscape elements in the winter season, wind can blow the warm radiation to adjust the weather. Moreover, Brown, and Gillespie, have been investigating the thermal comfort and energy efficiency. They observed that the local climate depends on the connection into the air, evaporation, and objects of heating at the micro-site (Robert D. Brown 2010.)

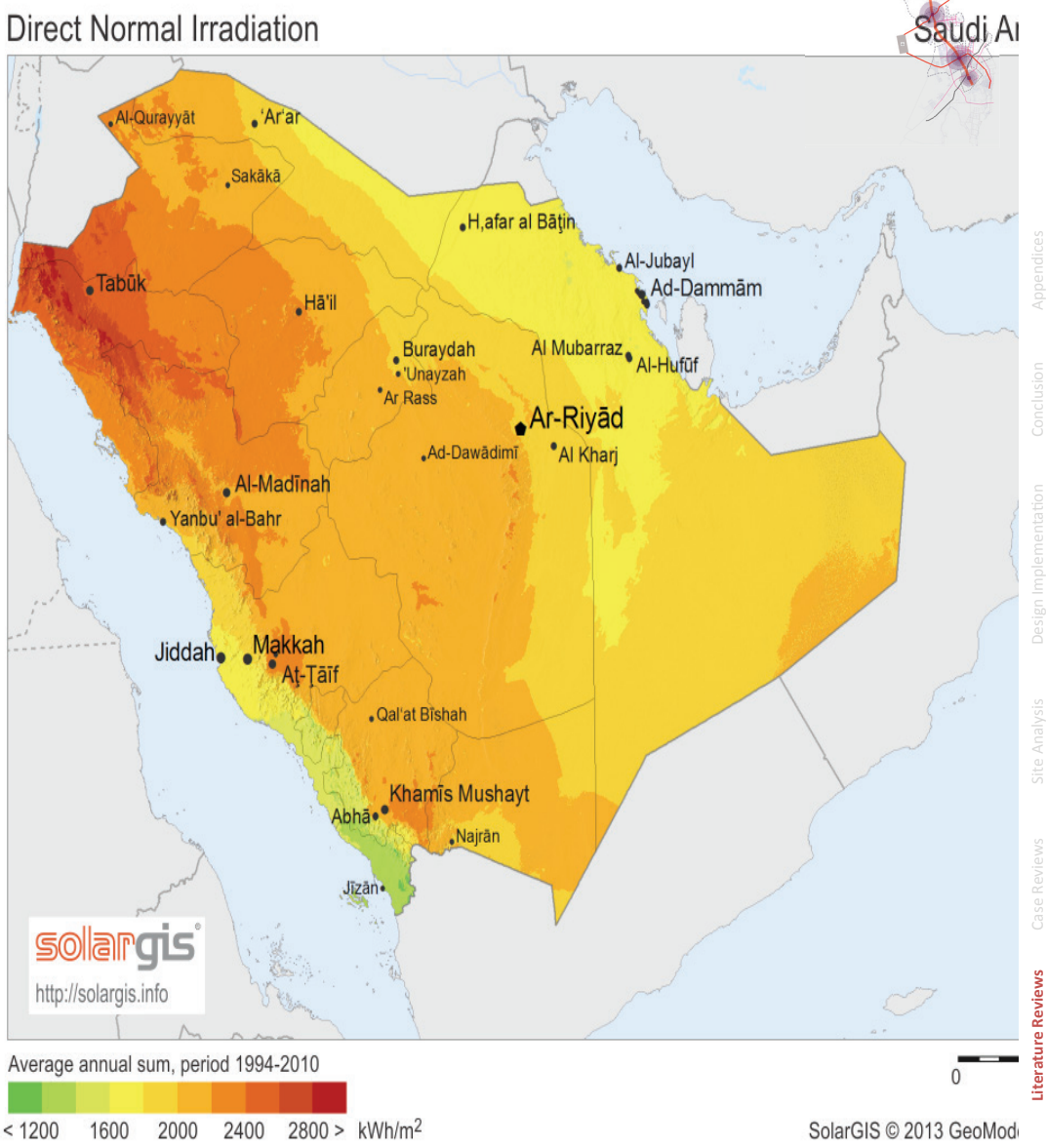
Public open space is most attractive place for people, but it may not be comfortable for them because of the climate quality (Bruse 2009). Therefore, we should reduce the urban impact in order to achieve best thermal comfort for humans. The outdoor environment depends on the individual perception factor, which can change the local micro-climate (Bruse 2009).

Solar Irradiation

Average direct irradiation is 1600 kWh/m2

Arizona has 2000 kWh/m2

Eastern Provience of Saudi get satisfiyng solar irradiation, which can raise the solar panels opportunities.



CASE REVIEWS

Multi-modal transit is one of the fastest growing trends in modern urban cities. There are many countries with urban cities suffering from the greenhouse affect, which dramatically threaten the climate condition by increasing the pollution and urban heat island. Consequently, many countries have become aware about modern modal of transit, and how to connect them with the community by allowing reliable walkability and accessibility. This chapter will address several successful projects that aim to connect its contexts with multi-hubs that provide variety of amenities for public and reduce pollution by using renewable energy methods.

TRASBAY TRANSIT CENTER, USA

SW. MONTGOMERY GREEN STREET, USA

PORTLAND MALL REVITALIZATION, USA

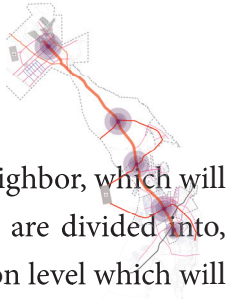
MASDAR CITY, UAE

RIYADH METRO, KSA

ALHARAMIN METRO, KSA

Key Concept: Hub with multi transit modal, renewable, walkability

http://www.designboom.com/architecture/transbay-transit-center-transforms-san-francisco-by-pelli-clarke-pelli/#sthash.1p7ZKDpZ.dpuf



Designed by: Pelli Clarke Pelli Architects (PCPA)

Client: The Transbay Joint Powers Authority (TJPA)

Size: 1.5 million square feet/2.2 hectare roof top

Cost: $4.5 billion

Construction: Begun in 2012 and expected to open in 2017

Awards: LEED Gold rating

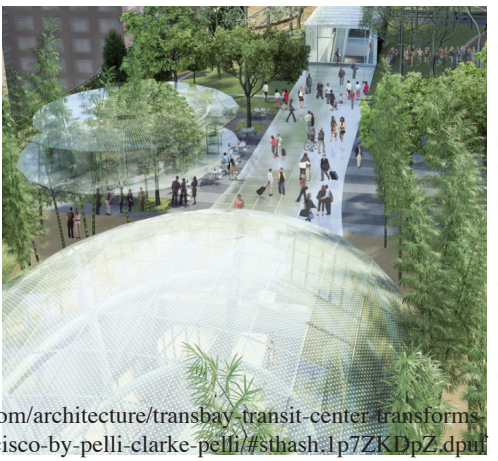
Design Implications:

Well connected -with transportation, pedestrian, and mixed use

Easy accessibility and circulation by using multi uses center, five different levels connecting the context with the station.

Increase job opportunities and renewable enrjy use

The Transbay Station contains five stories connected with its neighbor, which will accommodate strong accessibility and walkability. The stories are divided into, metro level which will be the lowest level, followed by the station level which will be as transition area between the bus stations and the metro. Above the metro station level, the bus station will be connected with the San Francisco buses routes. The bus station is the ground level which is connected with the center neighbors, and it allows walkability for public to pass through the transit. Lastly is the rooftop and it covers the hall transit with 2.2hectar; this roof connected with the surrounded high rise buildings, and provide variety of amenities for public with cautious of environment. The center is expected to serve more than 100.000 passenger per day, and 45 million per year. The city of San Francisco has a vision to connect the neighborhood with the transit hub by build affordable office and shopping centers, which will open a great opportunities for public. This transit will be connected with San Francisco downtown, where can provide reliable linkage for community and public.



http://www.designboom.com/architecture/transbay-transit-center-transforms-san-francisco-by-pelli-clarke-pelli/#sthash.1p7ZKDpZ.dpuf

Key Concept: Viability, Accessibility, Walkability, Flexibility, Community, Green Infrastructure

Light Rail/Streetcar

Lines of Rail Transportation **4**

Active Pedestrians

Average Sidewalk Width in Feet **17**

Bike Transit

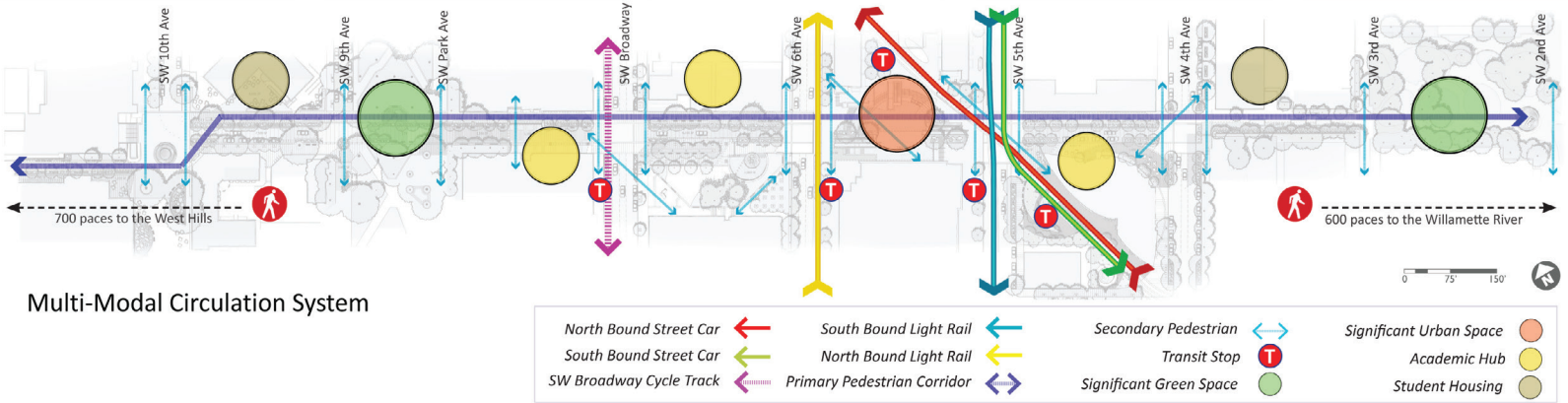
Additional Bike Spaces Provided **82**

Passive Pedestrians

Additional Benches for Seating **63**

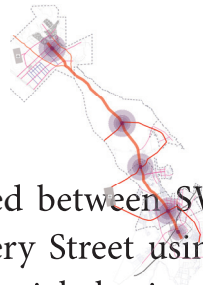
Electric/Hybrid Autos

Parking Spaces for plug-in parking **12**



Multi-Modal Circulation System

http://www.asla.org/2012awards/572.html



Designed by: Nevue Ngan Associates and Sisul Engineering

Client: Portland Development Commission (PDC), Portland's Bureau of Environmental Services

Size: 140 Square Miles 20 acres of rooftops

Cost: from $14 million to $52 million

Construction: Completed in 2009

Awards: ASLA

Design Implementation:

Successful connection between academic, public open space, public transportation, and residential context.

The designer try to make water harvesting visible for public, by using excessing fountain and reuse gray and storm water.

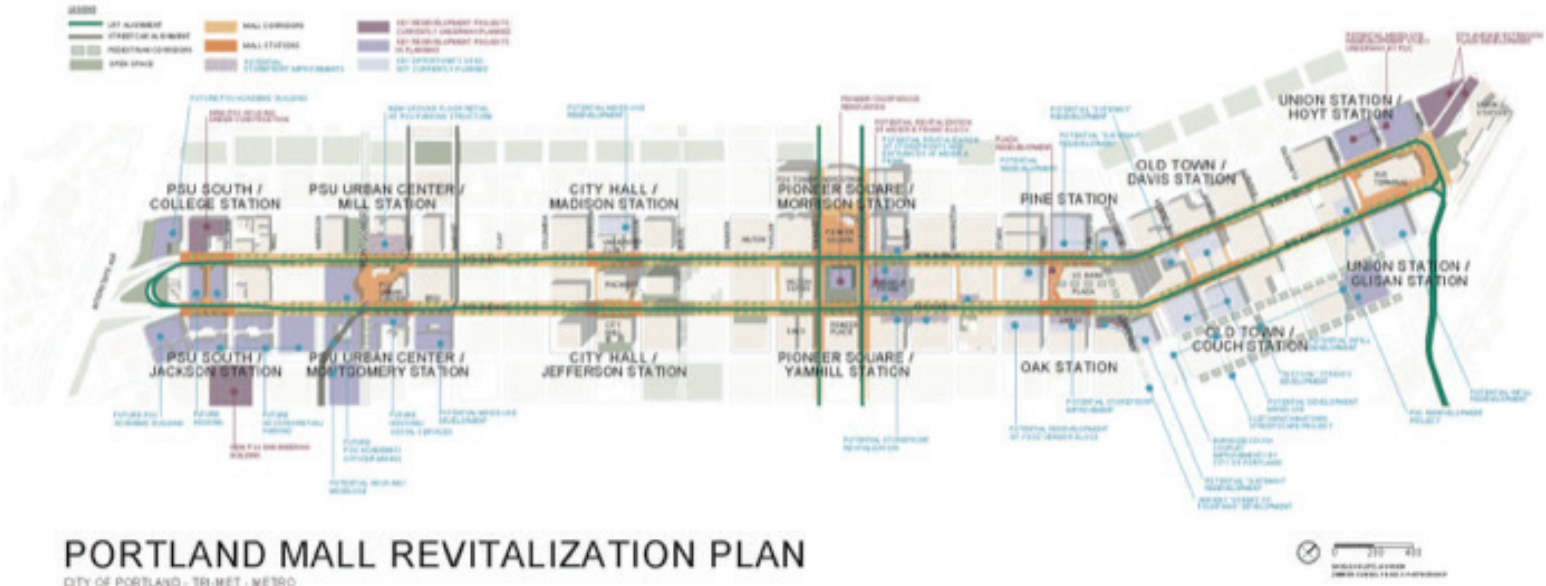
Provide active and passive area to enhance walkability.

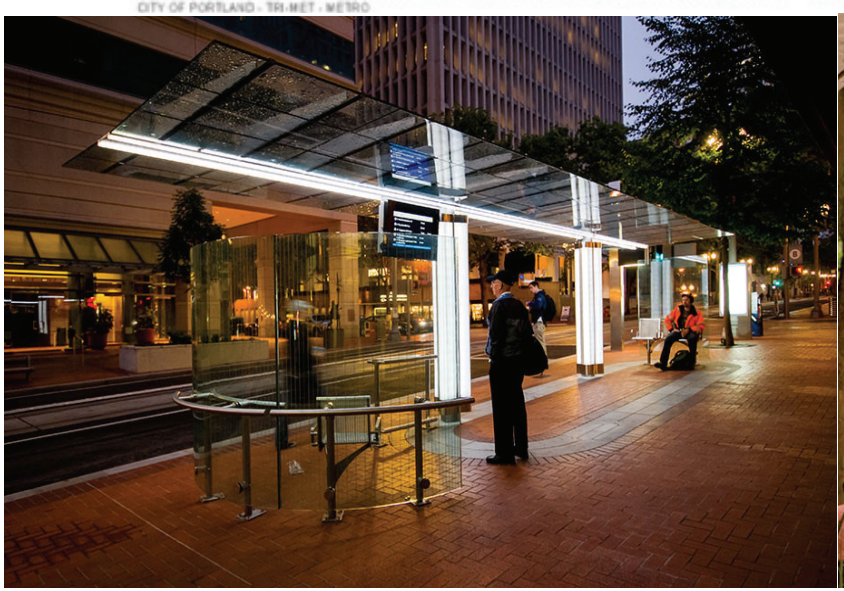
The aim of the project is to connect 9 blocks located between SW 11th Ave. E. to Petty grove Park via SW Montgomery Street using these elements; success connection between residential, business, and academic neighborhood, easy access to public transit and urban hubs, storm-water management with 1.8m gallons connected by the existing fountain, and enhance walkability and visibility among the site to Willamette River

This project was a collaboration between the Portland Development Commission (PDC), Portland Bureau of Environmental Services (BES), Portland State University, and Gerding Edlen Development. The development area is located between SW 11th Avenue east to Pettygrove Park, where SW Montgomery is lay between them. The project is divided between nine blocks; each block has different function and amenities for instance, passive and active area, open urban area, academic area, and shops. All these facilities will be linked by multi-transportation and water harvesting technics. Because of this corridor located among Portland State University and public space, the walkability and clear accessibility are the most important consideration to accomplish this project.

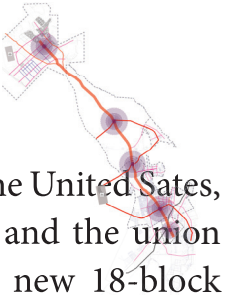
http://www.asla.org/2012awards/572.html

Key Concept: Viability, Civic Mall, Urban Mall, Walkability, Green Infrastructure





http://www.asla.org/2011awards/091.html



Designed by: Nevue Ngan Associates and Sisul Engineering

Client: Portland Development Commission (PDC), Portland's Bureau of Environmental Services

Size: 140 Square Miles 20 acres of rooftops

Cost: from $14 million to $52 million

Construction: Completed in 2009

Awards: ASLA

Design Implementation:

Define the role of the mall as a civic place

Enhance pedestrian, bicycle, automobiles, and high capacity bus

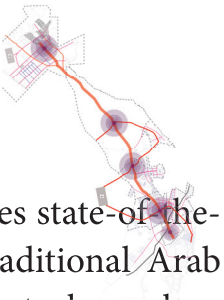
Provide 58 restored blocks intersection to enhance walkability

This project recognized as a largest transit surface in the United Sates, it's contain the old Portland mall blocks since 1978 and the union station which is built in 1994, connected with the new 18-block south extension to Portland State University. Although, connectivity and walkability are the main consideration in the Portland Mall, where can create several juts for pedestrian and transportation. The intersection of each block is well designed for pedestrian and multi transportation pass such as streetcar, light rail, automobile, bus, and bicycles. Also, providing 45 new transit shelters to serve the public and enhance the uses of public transportation (ZGF.)

http://www.asla.org/2011awards/091.html

Key Concept: High-Tech, Cooling Tower, Solar and wind energy, Net Zero City

http://www.dezeen.com/2009/08/28/masdar-city-centre-by-lava/



Designed by: Foster + Partners

Client: Masdar-Abu Dhabi Future Energy Company

Size: 6,000,000m²

Cost: US$2.5 billion

Construction: Started in 2007, under construction

Awards: Global Renewable Energy, Sustainable City of the Year.

Design Implementation:

High technologies with renewable energy

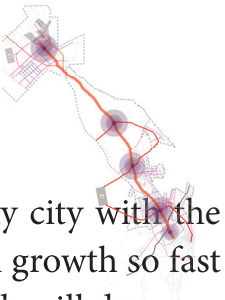
Sustainable landscape planning trends
Multi transit model with variability
Green infrastructure

Similar climate zone of the Eastern Region and uses of native materials

According to Foster+Partners, "Masdar City combines state-of-the-art technologies with the planning principals of traditional Arab settlements to create a desert community that aims to be carbon neutral and zero waste. The 640-hectare project is a key component of the Masdar Initiative, established by the government of Abu Dhabi to advance the development of renewable energy and clean-technology solutions for a life beyond oil. The city will become a center for the advancement of new ideas for energy production, with the ambition of attracting the highest levels of expertise. Knowledge gained here has already aided the development of Abu Dhabi's 'Estidama' rating system for sustainable building."

Key Concept: High-Tech, Cooling Tower, Solar and wind energy, Native Materials

http://riyadh-metro.com



Designed by: Foster + Partners

Client: Arriyadh Development Authority

Size: 176 km six-line

Cost: $ 22 Bilion

Construction: Construction begin in 2013, expected to finish in 2019

Design Implementation:

Dealing with Saudis culture and climate

Different types of inter-modal transit (bus, shuttle, and taxi)

Using native materials to reduce sub heat (plant, cooling towers, and water harvesting)

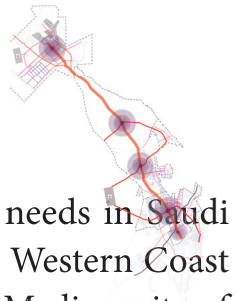
Riyadh Metro will connect King Abdullah Economy city with the neighbors and public spaces. Riyadh is expanding in growth so fast and this expanse requires good transportation, which will decrease the congestion of traffic. There are four main stations located among high density and downtown of Riyadh. The metro route is 178km (110.6mi) with six lines and eighty-five stations, divided underground, and elevated.

Each station will have different theme, and all of them using high technologies and solar panels. By using renewable energy techniques, each station will reduce electricity uses more than 20%. Although, hot climate in Saudi requires colling techniques such as wind catcher, cooling tower, and shade structures, which will be focused on this project (Riyadh-metro.com.)

http://riyadh-metro.com

Key Concept: High-Tech, Cooling Tower, Tremendous Passengers, Islamic Theme

http://www.saudirailways.org



Designed by: Foster + Partners , Co-architects: Buro Happold, Joint venture. Dar Al Riyadh

Client: Saudi Railways Organization

Size: 240m²

Capacity: Projected 2012: 60million, 2022: 80 million, 2042: 135 million

Cost: $8 billion

Construction: Started in 2009, and expected to open in 2017

Design Implementation:

Dealing with huge multi-culture visitors

Different types of inter-modal transit (bus, shuttle, and taxi)

Using native materials to reduce local heat by (plant, cooling towers, and water harvesting)

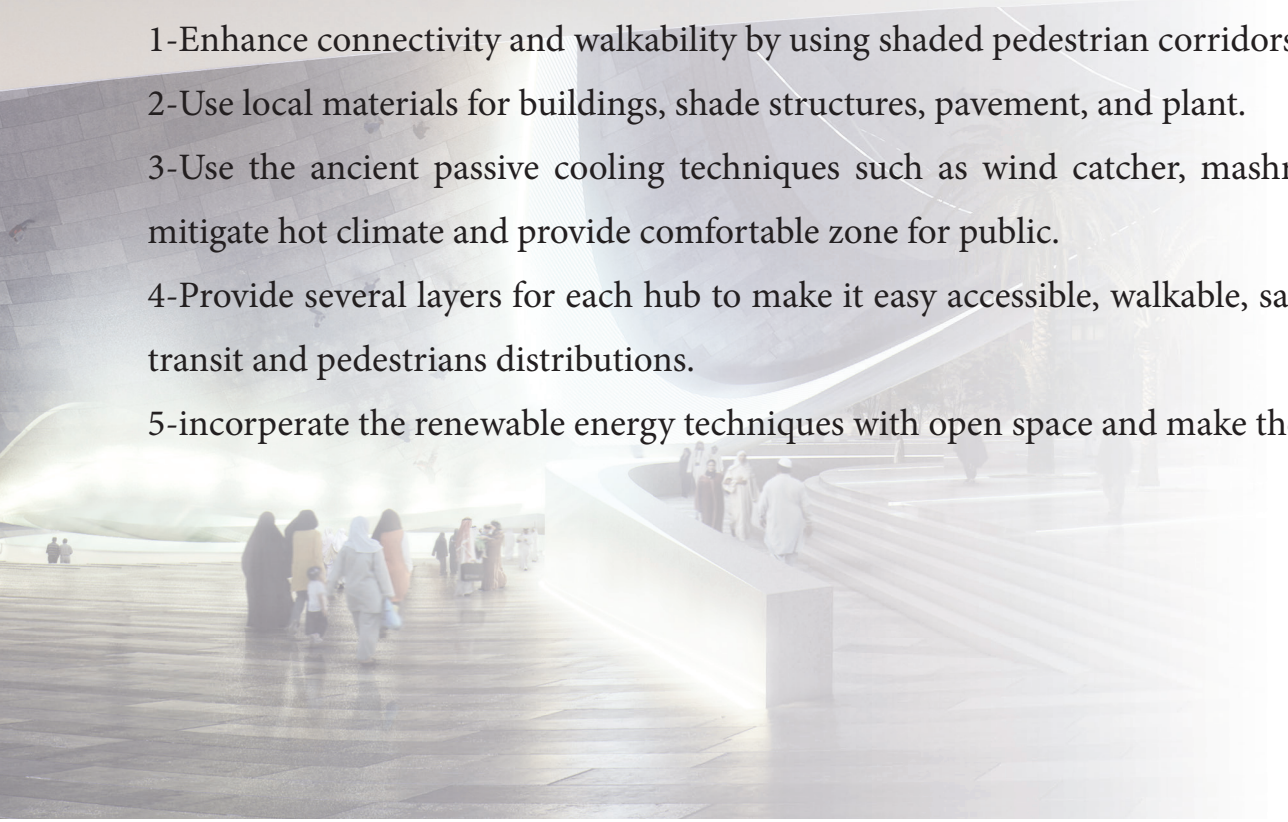
Alharamin Metro is on of the main transportation needs in Saudi Arabia. This metro will link three major cities at the Western Coast of Saudi, the holy city Makkah, the Holy mosque in Medina, city of Jeddah, and King Abdullah Economic City. There are tremendous visitors to the holy cities traveling from City of Jeddah airport.

According to Foster+Partners, "Altogether, the large, flexible stations will cover an area more than 30 times the size of London's Trafalgar Square and will initially accommodate an anticipated 60 million passengers approximately six times the number of passengers that take the Eurostar from St Pancras each year.

http://www.saudirailways.org

The case reviews addressed several successful projects, that aimed to connect the context of this research with multi-hubs that provide variety of amenities for public and reduce pollution by using Renewable energy methods. There are several implications should be considered when designing adesign a multi-modal transit corridor:

1-Enhance connectivity and walkability by using shaded pedestrian corridors, multi-transits.
2-Use local materials for buildings, shade structures, pavement, and plant.
3-Use the ancient passive cooling techniques such as wind catcher, mashrabia, and qanat system, to mitigate hot climate and provide comfortable zone for public.
4-Provide several layers for each hub to make it easy accessible, walkable, safe for pedestrian, and avoid transit and pedestrians distributions.
5-incorperate the renewable energy techniques with open space and make them visible for public.



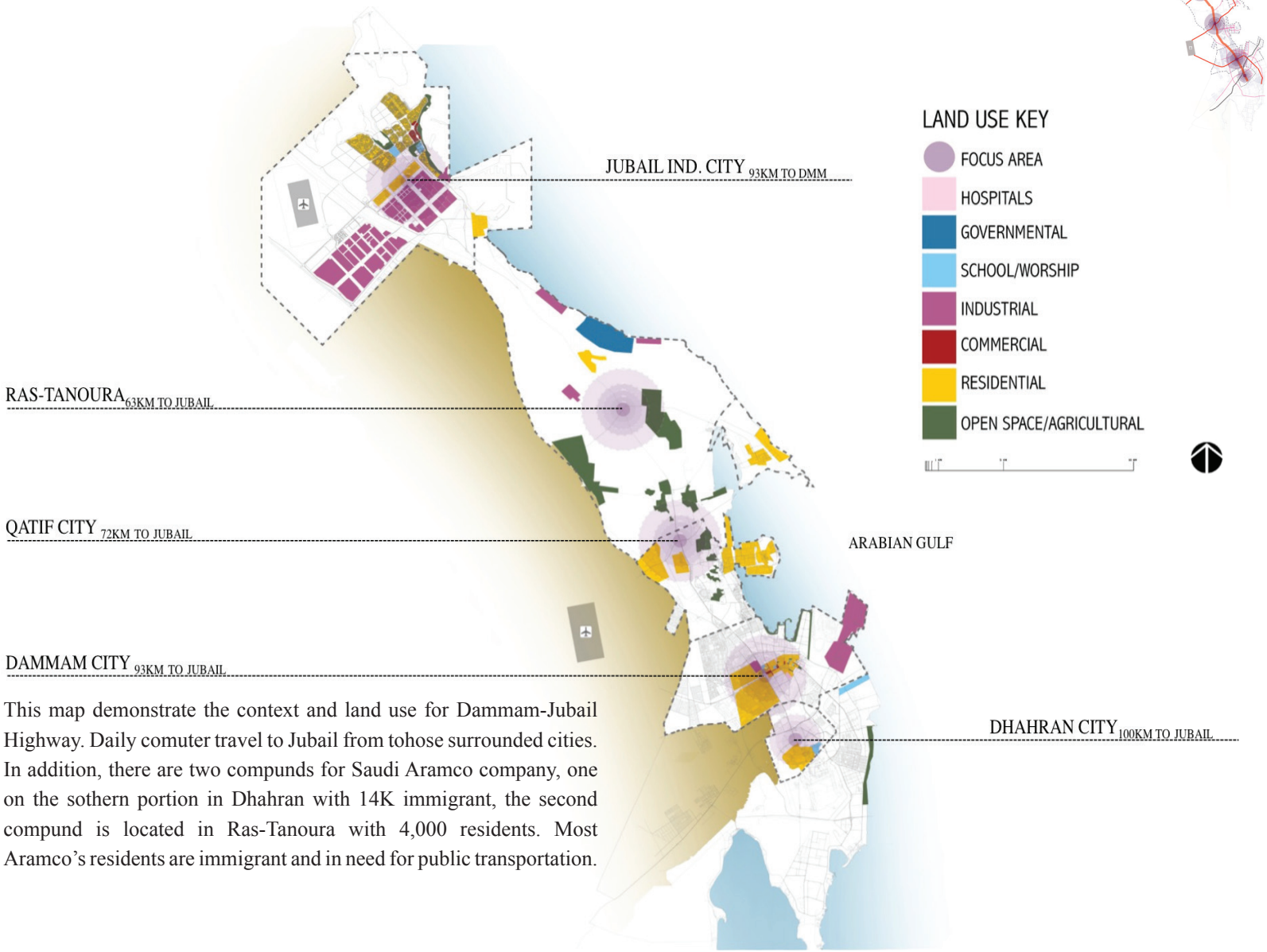
SITE ANALYSIS

LOCATION

REGIONAL ANALYSIS
-Contexts
-Climate
-Open space/agriculture/hydrology
-Circulation
-Synthesis

INDUSTRIAL HUB ANALYSIS
-Existing features
-Circulation
-Synthesis

Jubail Industrial City is located on
the Arabian Gulf, 100 kilometers north of the Dammam metropolitan area. This unique location gives it two major advantages; accessibility to international sea-lanes through the Gulf and proximity to sources of energy and raw materials for refining and petrochemical production.



This map demonstrate the context and land use for Dammam-Jubail Highway. Daily comuter travel to Jubail from tohose surrounded cities. In addition, there are two compunds for Saudi Aramco company, one on the sothern portion in Dhahran with 14K immigrant, the second compund is located in Ras-Tanoura with 4,000 residents. Most Aramco's residents are immigrant and in need for public transportation.

REGIONAL SITE ANALYSIS

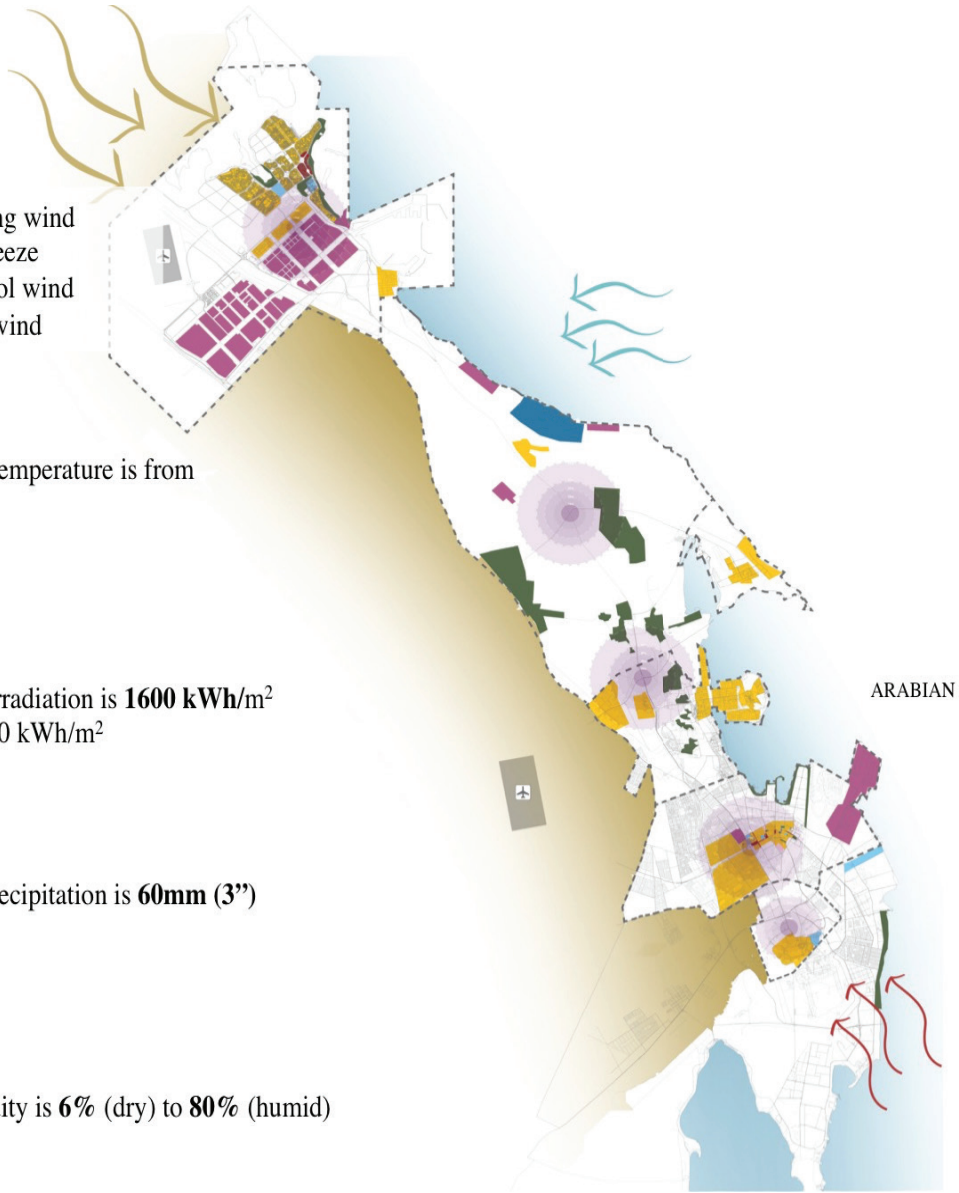
SW-N prevailing wind
E. Wind, sea breeze
SE. seasonal cool wind
SW-W, Sandy wind

The average of temperature is from 10°C to 45°C

Average direct irradiation is **1600 kWh/**m^2
Arizona has 2000 kWh/m^2

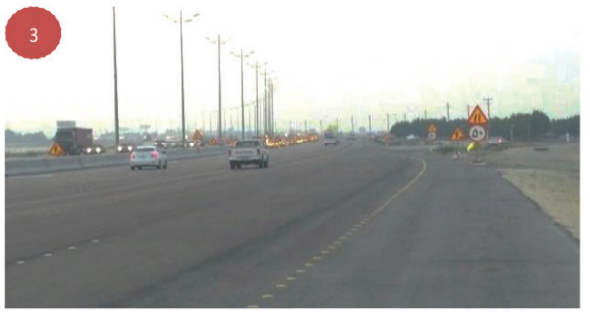
Highest rain precipitation is **60mm (3")**

Average humidity is **6%** (dry) to **80%** (humid)



LAND USE KEY

- FOCUS AREA
- HOSPITALS
- GOVERNMENTAL
- SCHOOL/WORSHIP
- INDUSTRIAL
- COMMERCIAL
- RESIDENTIAL
- OPEN SPACE/AGRICULTURAL

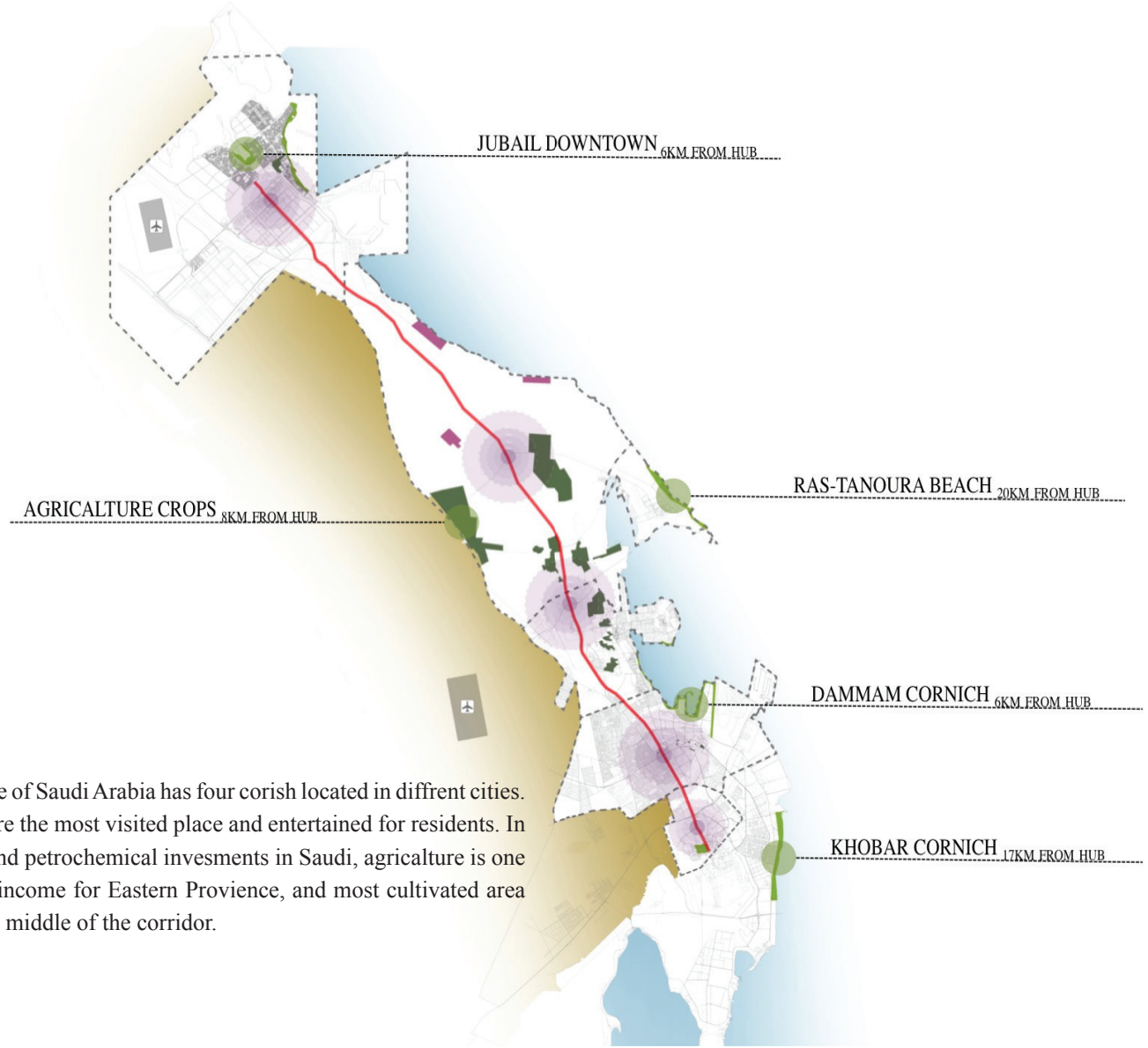


Problems:

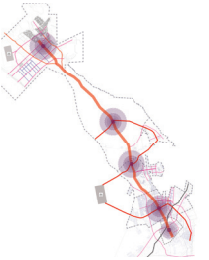
Congestions and accidents on Dammam Jubail Highway (3)

Lack of Vegetation (2)

Disconnected lands (1)



Eastern Provience of Saudi Arabia has four corish located in diffrent cities. Those cornsihs are the most visited place and entertained for residents. In addition for oil and petrochemical invesments in Saudi, agricalture is one one of the main income for Eastern Provience, and most cultivated area are located in the middle of the corridor.



INDUSTRIAL

Jubail Industrial City

+Hub – Factories – Parks –Renewable Energy

+Employees - Public

-Provide **safe and satisfy** hub for commuter

-Enhance **walkability** between industrial, residential, and public space

AGRICULTURAL

Qatif, Tarout, Ras Tanoura

+Hub – Farms – Fishing - Rest Areas – Renewable Energy

+Public – Farmers – Fishermen – Commuter

-Enhance **connectivity** and **walkability**

-Expand **agricultural fields** and connect it with farmer markets

-Provide **rest areas** with an access to the **shoreline**

-Water **Harvesting** techniques

URBAN

Dammam, Dhahran,Al Khobar

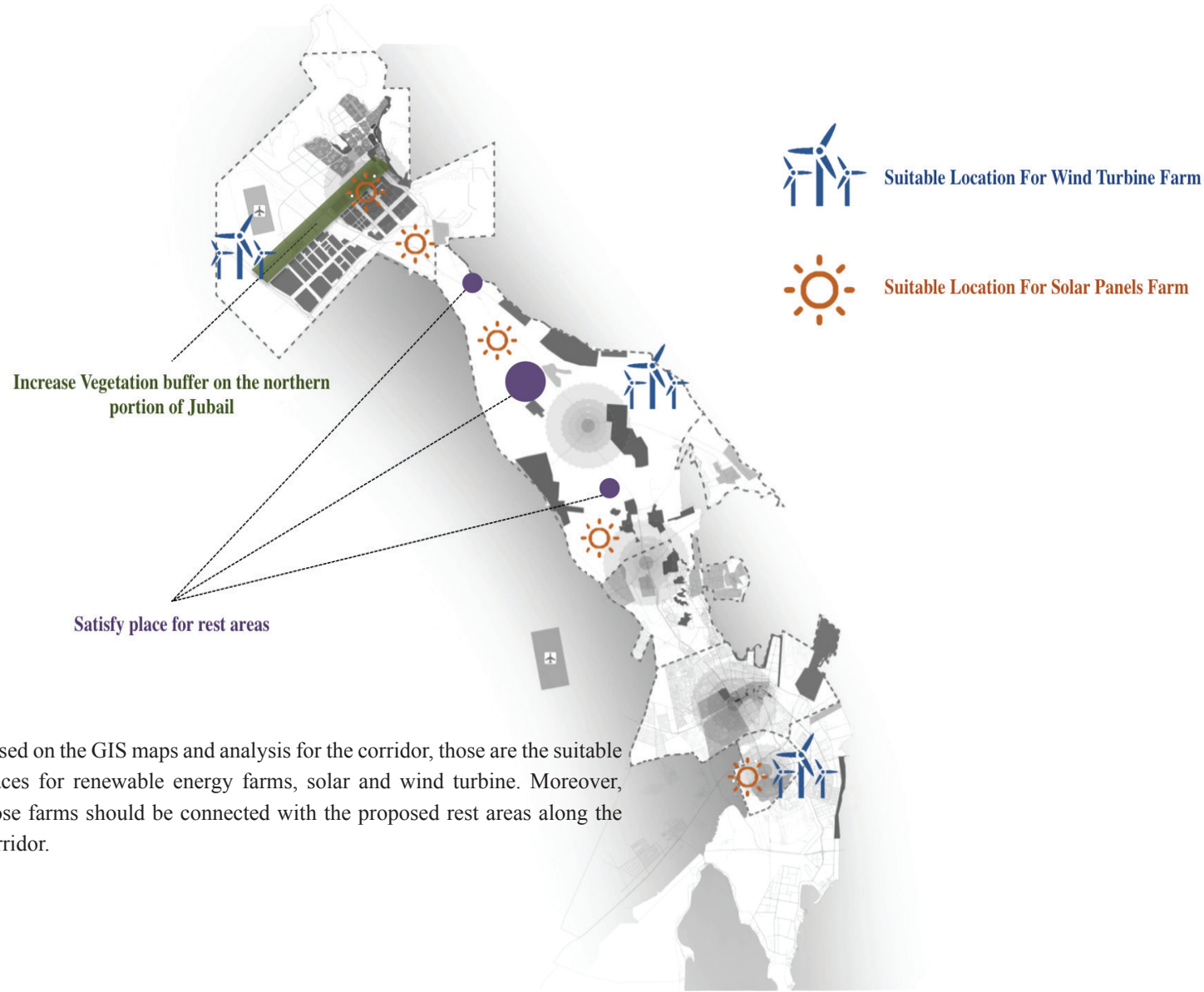
+Hub – Airport – Port –Renewable Energy

+Public – Commuter

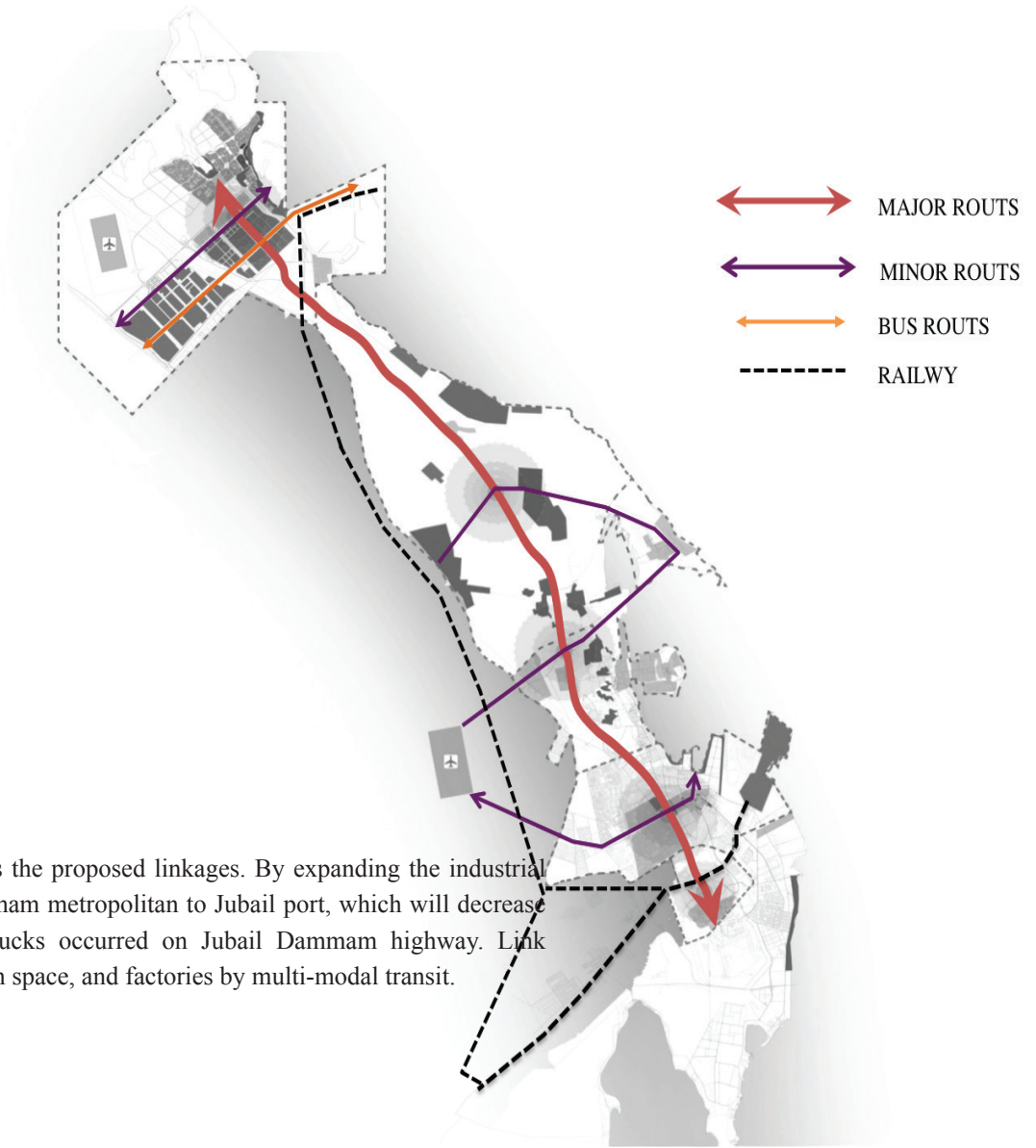
-Transfer **commuter** from point c to a

-**Link** Dammam, Al-Khobar, and Dhahran by **multimodal transit** (lrt,streetcar,bus,bikes,pedestrian)

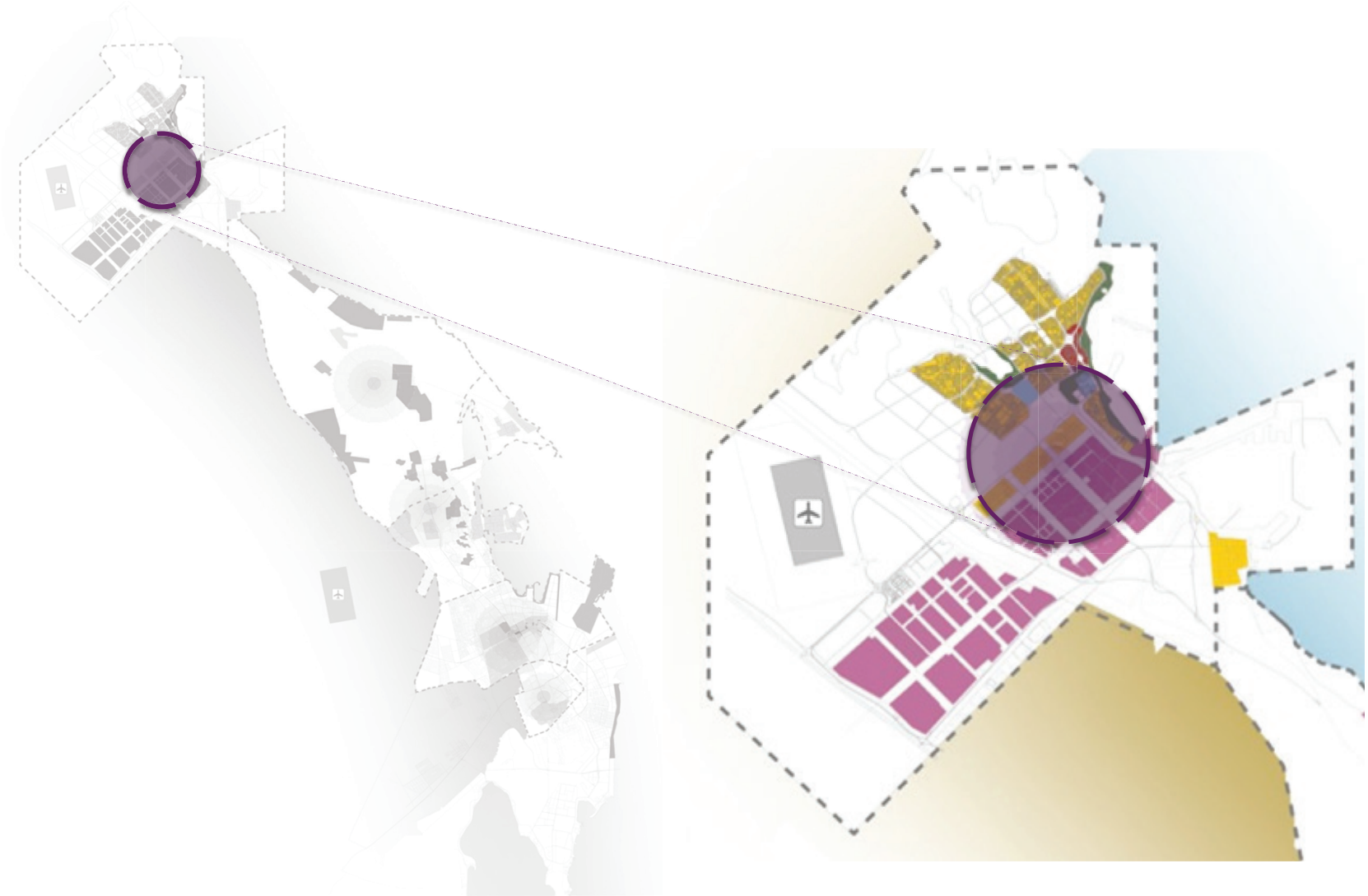
-Use **Solar** panels and **Wind** Turbine to **generate energy** for the LRT and stations

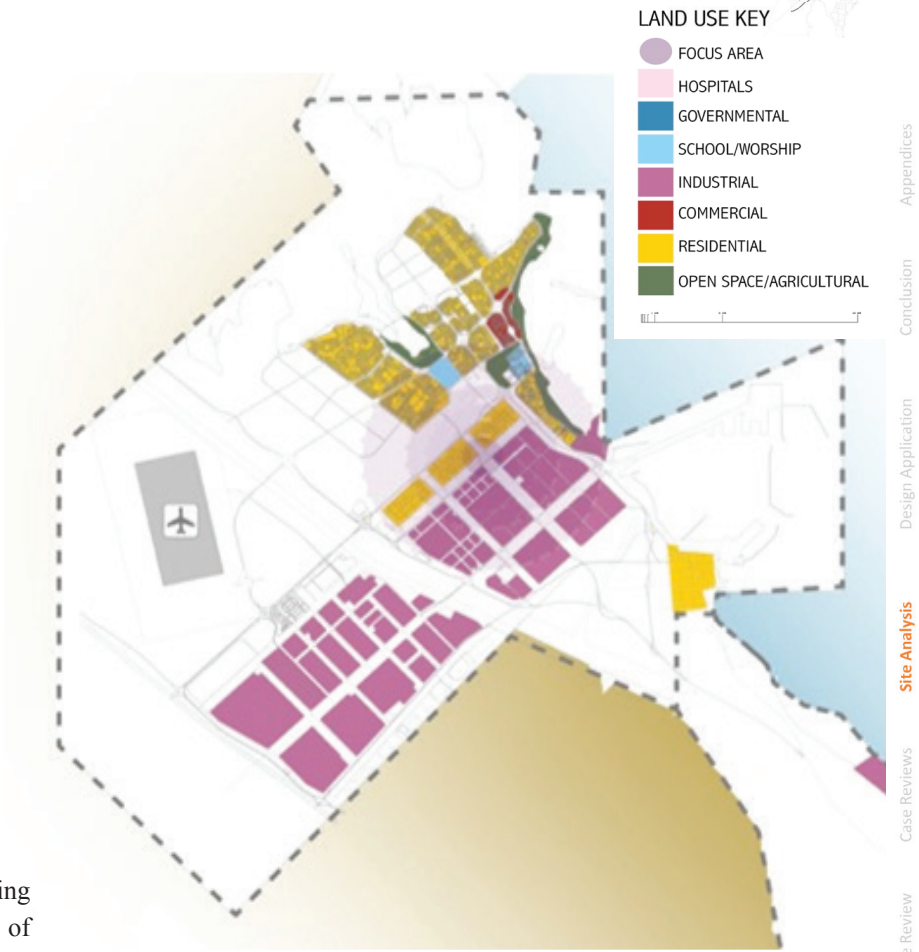


Based on the GIS maps and analysis for the corridor, those are the suitable places for renewable energy farms, solar and wind turbine. Moreover, those farms should be connected with the proposed rest areas along the corridor.



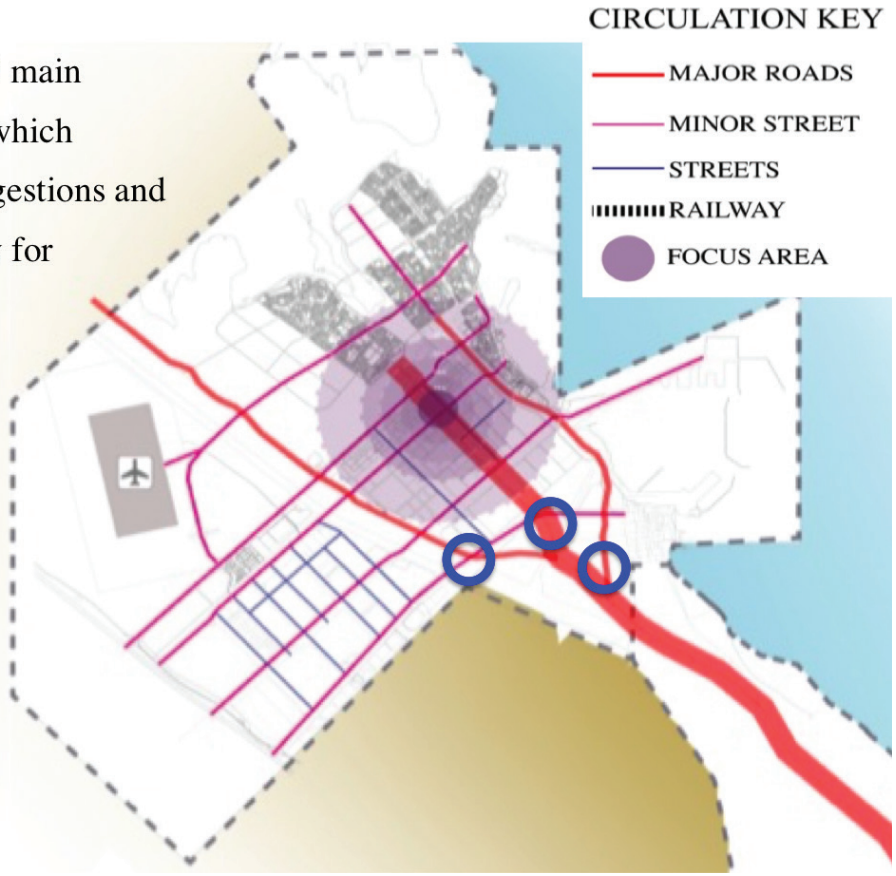
This map illustrates the proposed linkages. By expanding the industrial railway from Dammam metropolitan to Jubail port, which will decrease congestions that trucks occurred on Jubail Dammam highway. Link airports, crops, open space, and factories by multi-modal transit.

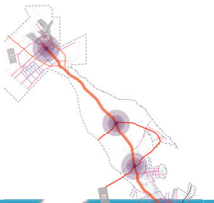




Jubail is significantly located on international trade zone. Jubail planning is unique, where the industrial area located at the southern portion of Jubail to avoid its smoke. The residential area located in the northeast part of Jubail, connected with satisfies amenities.

Jubail has 3 main entrances, which reduce congestions and give variety for commuter





- Use intersections as a transitional nodes
- Incorporate the water canals with irrigation, cooling, and aesthetic use
- Provide valuable walkability and connectivity
- Increase vegetation buffer to reduce Co2
- Connect the hub with linear park and green streets

INTERSECTION (NODE)

HUB

WALKABLE STREETS

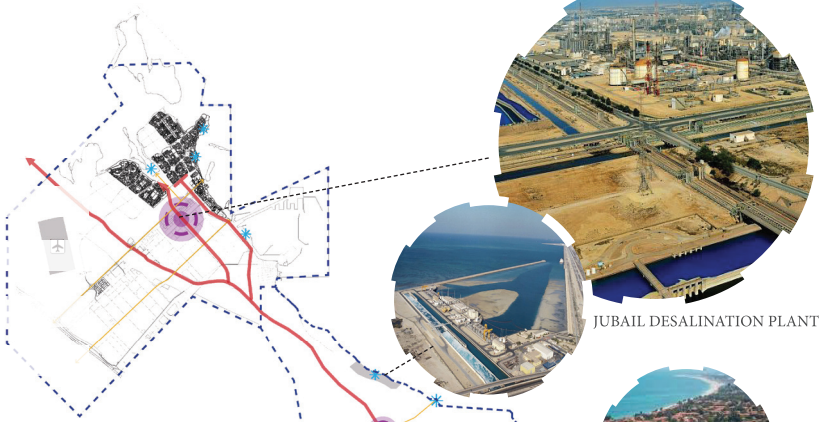
WATER CANALS

VEGETATION

SITE ANALYSIS SUMMARY

LEGEND

- AGRICULTURAL AREA
- INDUSTRIAL/AIRPORT
- SCENIC/REST/AMENITIES
- PROPOSED STATIONS
- MAJOR HIGHWAY
- MINAR HIGHWAY



INDUSTRIAL HUB "JUBAIL"

THE TARGET ON THIS HUB ARE THE EMPLOYEES WHO DAILY COMMUTE TO JUBAIL INDUSTRIAL AREA. THEREFORE, THIS HUB WILL HAVE AN INDUSTRIAL STYLE THAT PREPARE EMPLOYEE TO THEIR FACTORY.

JUBAIL DESALINATION PLANT

RAS TANOURA ARAMCO COMPAND

AGRICULTURAL HUB "QATIF"

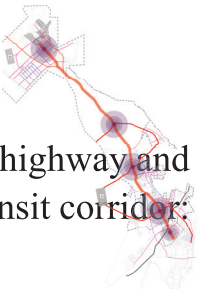
THIS HUB FOCUS INTO THE AGRICULTURAL THEME BECAUSE OF THE SURROUNDED AGRICULTURE FIELDS. THIS HUB WILL CONTAIN VARIETY OF OUTDOOR FACILITY THAT WILL INCREASE THE INCOME OF THE QATIF, TAROUT, AND RAS TANOURA.

URBAN HUB 'DAMMAM METROPOLITAN'

THIS HUB IS THE HART OF DAMMAM CITY, WHICH INTERSECT DHAHRAN-JUBAIL HIGHWAY WITH AIRPORT ROAD. THIS HUB PROVIDE URBAN CONNECTIVITY AND EASY WALKABILITY.

RENEWABLE ENERGY HUB "ARAMCO"

THIS HUB IS WILL BE LINKED WITH ALMIDRA TOWER, KING ABDULAZIZ INTERNATIONAL CULTURAL CENTER, AND DHAHRAN EXPO. THIS HUB WILL PROVIDE AN ADVENTURE EXPERIENCE OF ENERGY FOR PUBLIC.



To summaries, the results of examine and analyzing the existing condition of Dammam-Jubail highway and its context, there are several considerations should be taken to accomplish the Multi-modal transit corridor:

1-Provide three main hubs based on the city theme, urban for Dammam metropolitan, agricultural for Qatif City, and industrial for Jubail industrial city.

2-Link Saudi Aramco's compounds to serve the residents and employee who commute every day to Jubail.

3-Link airports, Cornish, open spaces, and districts with public transportation such as bus, streetcar, light rail, freight, bicycles, and vehicle.

4-Provide rest areas along the corridor, which will enhance connectivity between the suburban and urban cities.

5-Link Jubail Industrial City with the residential area by pedestrian corridor connected with multi-modal transit and parks.

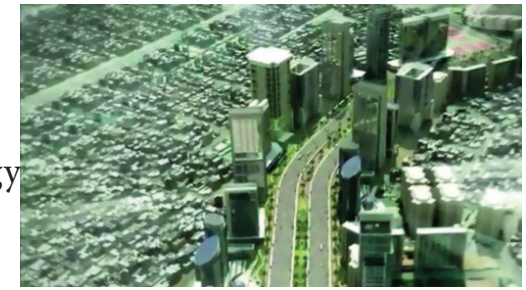
6-Use all the vacant lands that located in the industrial area as open space and incorporate the sea water canal to irrigate the vegetation and aesthetic uses.

7-Enhance renewable energy use such as solar panels, wind catcher tower, and water harvesting.

DESIGN APPLICATION

Overarching Goal:

Provide satisfying amenities and enhance walkability and connectivity along Dammam - Jubail Highway that can serve the commuter and increase the income for the Eastern Province, while considering uses for renewable energy



Objectives:

1- Provide multi-modal transit to serve commuter and public.

2-Provide satisfying amenities within walking distance from the hub.

3-Enhance renewable energy use to generate electricity for the hub and transit.

Objective	Activates	Elements	Qualitative characteristics	Quantities characteristics
create valuable connectivity and mobility between the hub and public space	-transit -walking -biking	lrt, streetcar, vehicles, bus, bicycles, pedestrian walkway, trails, station, bridges, underpass, parking garage	-encourage using multimodal transportation -enhance walkability -integrate industrial theme with public	-2 lrt lanes one focus into employees and students, and the second one for public -buses serve the employee -streetcar linking recreation, work, and hub
provide satisfy places that can integrate commuter with public	-seating -learning -resting -gathering -recreational	civic plazas, interpretive center, rest area, cafe, mini market, affordable offices, affordable housing, farm market, gem show, sports field	-provide a civic place where public can experience each hub -mixed use to increase the income -provide entertainment to serve employees	-museum of industry -mall of industry -shaded industrial plaza -gulf cars for tour -lockers, shower, sport court -24 hours market and restaurant
enhance renewable energy uses and arid climate remediation to reduce co2 emissions	-renewable energy -water harvesting -passive cooling strategies	solar panel farms, wind farms, cooling tower, shading structures, bio swale, detention basins, water tanks	-use renewable energy to run the lrt and stations -mitigate hot temperature and provide human thermal comfort	-wind catcher -mashrabia (wood shade structure) -detention basins attached with the cooling canal, and collecting runoff

Based on the literature review, case reviews, site analysis, and GIS maps, these are the regional strategies that should be considered to design Dammam-Jubail multimodal corridor. These strategies will be accessible and easy to use for future phases development.

This research focused into phase A, which is the industrial hub, located in Jubail industrial city. Because Jubail's commuter faces all these planning problems such as, lack of public transportation, high accidents rate, mobility congestions, and air pollution, This research devoted to solve all these issues.

URBAN

Dammam, Dhahran,Al Khobar

+Hub – Airport – Port –Renewable Energy

+Public – Commuter

AGRICULTURAL

Qatif, Tarout, Ras Tanoura

+Hub – Farms – Fishing - Rest Areas – Renewable Energy

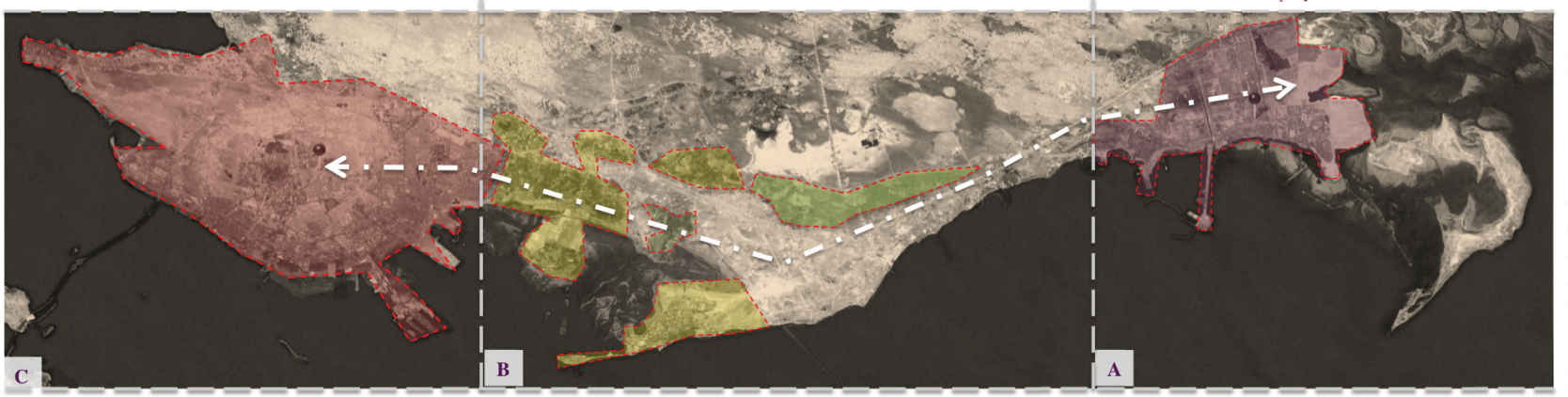
+Public – Farmers – Fishermen – Commuter

INDUSTRIAL

Jubail Industrial City

+Hub – Factories – Parks –Renewable Energy

+Employees - Public



-Transfer **commuter** from point a to c

-**Link** Dammam, Al-Khobar, and Dhahran by **multimodal transit** (lrt,streetcar,bus,bikes,pedestrian)

-Use **Solar** panels and **Wind** Turbine to **generate energy** for the LRT and stations

-Enhance **connectivity** and **walkability**

-Expand **agricultural fields** connected with farmer markets

-Provide **rest areas** with an access to the **shoreline**

-Water **Harvesting** techniques

-Provide **safe and satisfy** hub for commuter

-Enhance **walkability** between industrial, residential, and public space

EDUCATIONAL THEME

This concept is focus into EDUCATIONAL theme

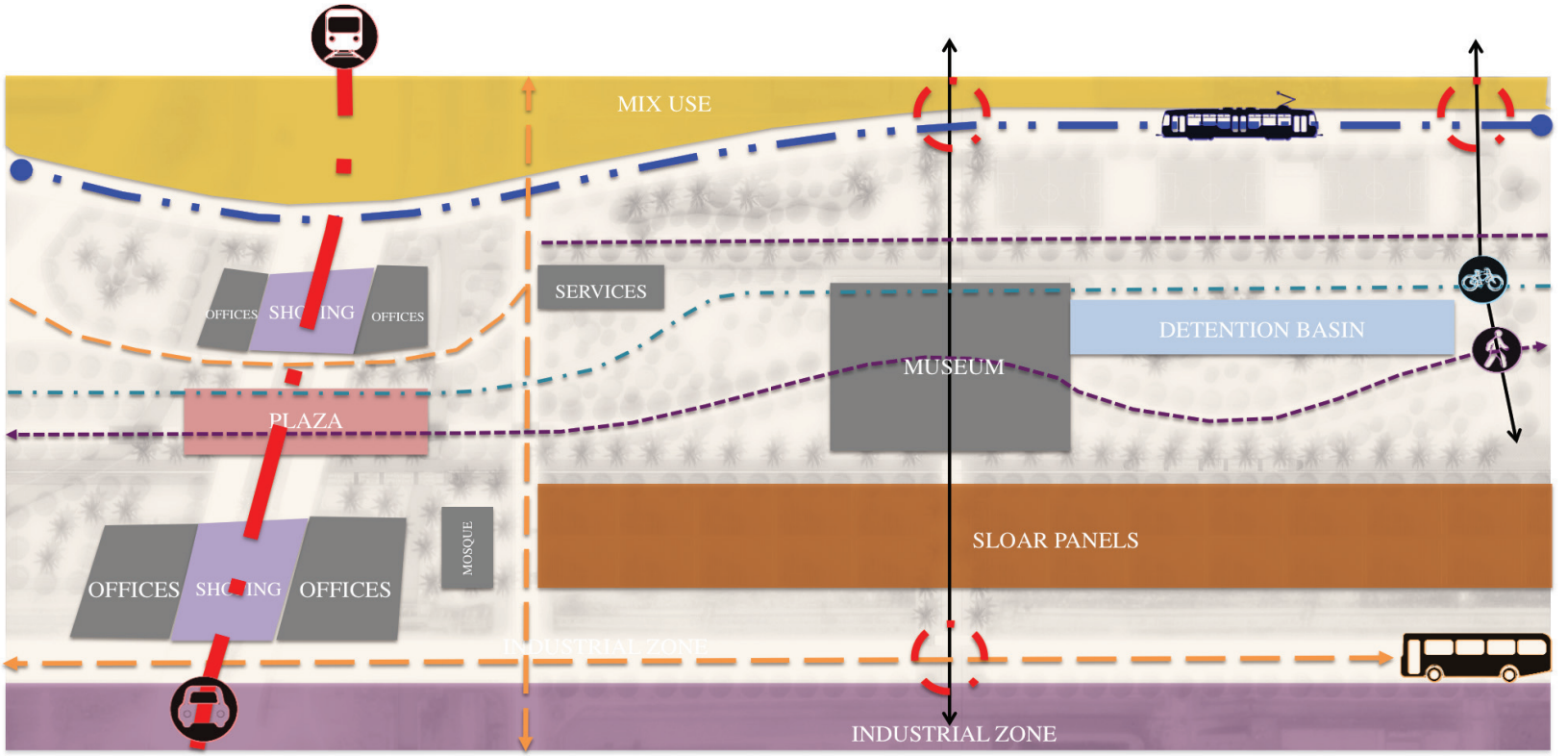
-Enhance connectivity and walkability between transit, industrial area, residential area, and seafront
-Stations within walking distance
-Pedestrian and bicycles routs
-Parking garage
-Bus and light rail station
-Linear park with riparian area

Pros

-Provide educational facilities serve the visitors
-Easy access and walkable axis from contexts
-Streetcar serve the residential district
-Provide harvesting techniques to educate public

Cons

-transits is not connected in one hub
-lack of shaded area
-transit stops are limited


MIX USE
OFFICES
SHOPPING
OFFICES
SERVICES
DETENTION BASIN
MUSEUM
PLAZA
MOSQUE
SLOAR PANELS
OFFICES
SHOPPING
OFFICES
INDUSTRIAL ZONE
INDUSTRIAL ZONE

CIVIC INDUSTRIAL

This concept is compiled of RECREATIONAL and EDUCATIONAL concepts, to become a INDUSTRIAL CIVIC theme

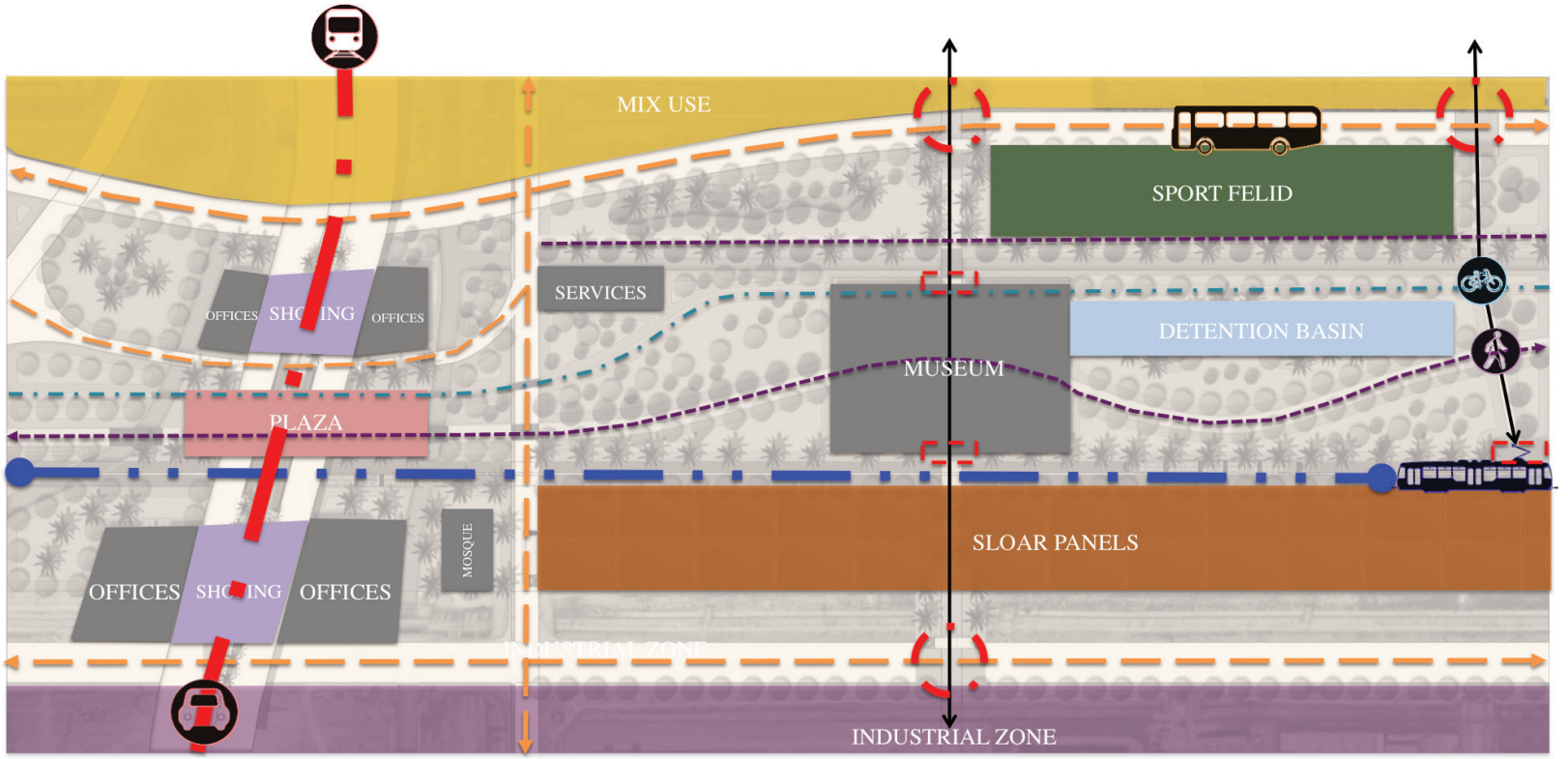
-Enhance connectivity and walkability among the central span
-Stations within walking distance for bus and street car
-Pedestrian and bicycles routs
-Parking garage
-Bus and light rail station
-Museum of industry

Pros

-Well connected pedestrian, transit, and facilities
-Variety of stops and axis
-Amenities serve commuter and residents

Cons

-Massive solar panels farm
-Large green area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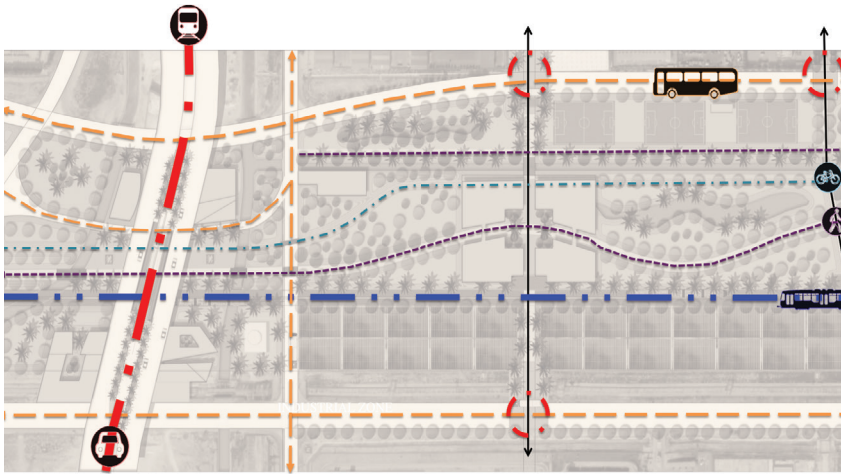
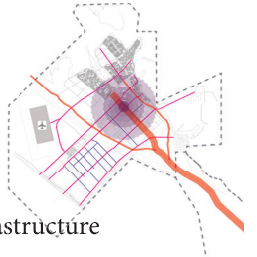
Zoning

Circulation



The final Master plan is addressing all the multi-modal transit and connectivity between the industrial hub, industrial factories, residential, linear park, and seafront. The industrial hub connected to a shopping mall, gift shop, multi-transit stations, offices, parking garage, and underpass plaza. The hub is targeting industrial companies in Jubail and provide a unique place for them to observe and manage their factories, also enjoy the spectacular view of the linear park and easy access to and from different cities. All the amenities are within walking distance and will serve the employee 24 hours because they have a different work schedule. The linear park contains active and passive areas connected with residential and industrial areas by green streets and transit stops, which will enhance connectivity, and walkability. The project provides several renewable energy techniques such as solar panels farm, seawater cooling canal, water harvesting, and cooling towers. The seawater cooling canal is the iconic feature that will cool the industrial hub, irrigate plants, aesthetic use such as fountains and lakes. Finlay, museum of industry located in the middle of the linear park, which will provide rich information about Jubail industrial city and provide tours for the visitors.

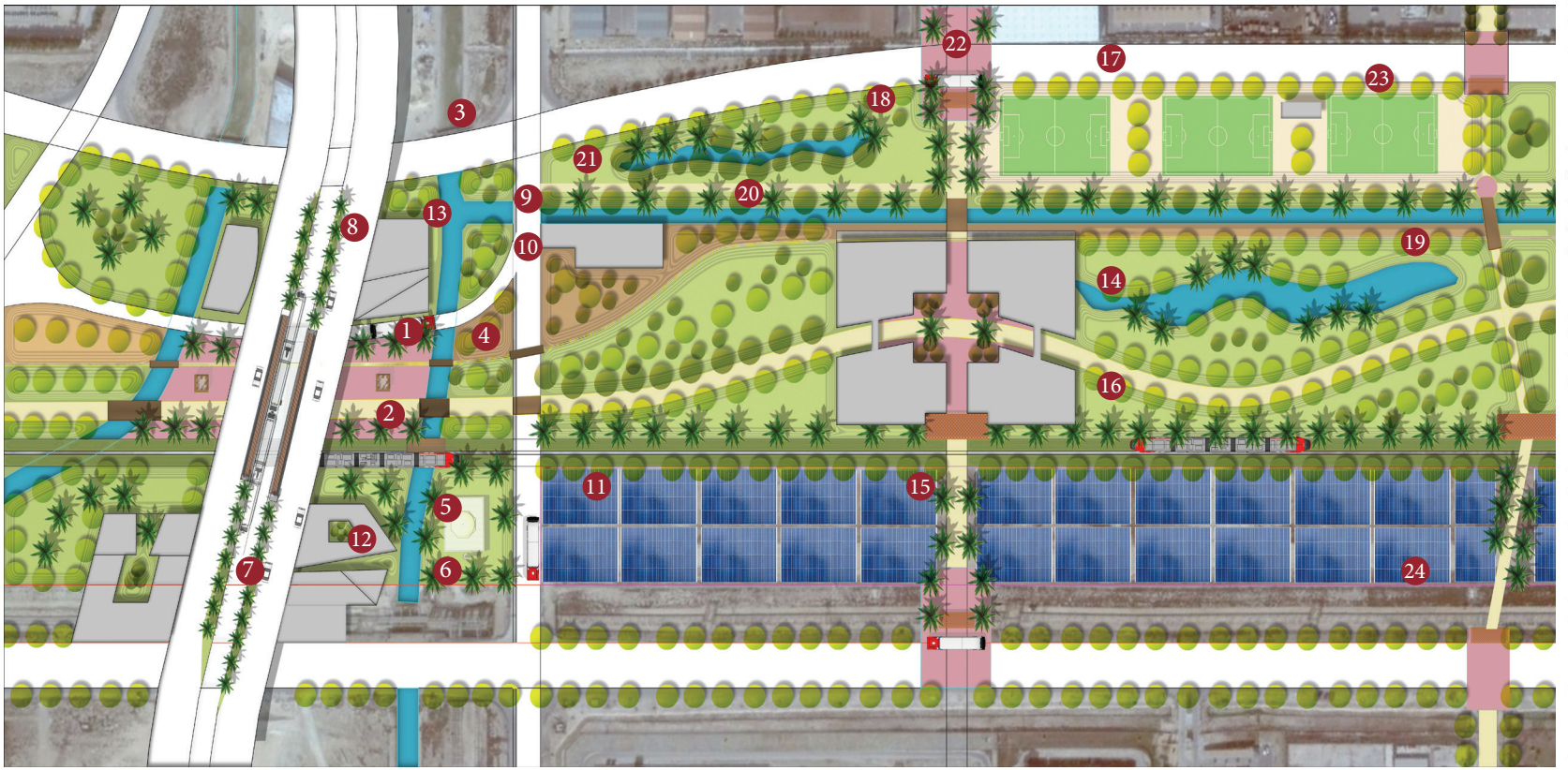


Master Plan

10m 30m 50m 100m

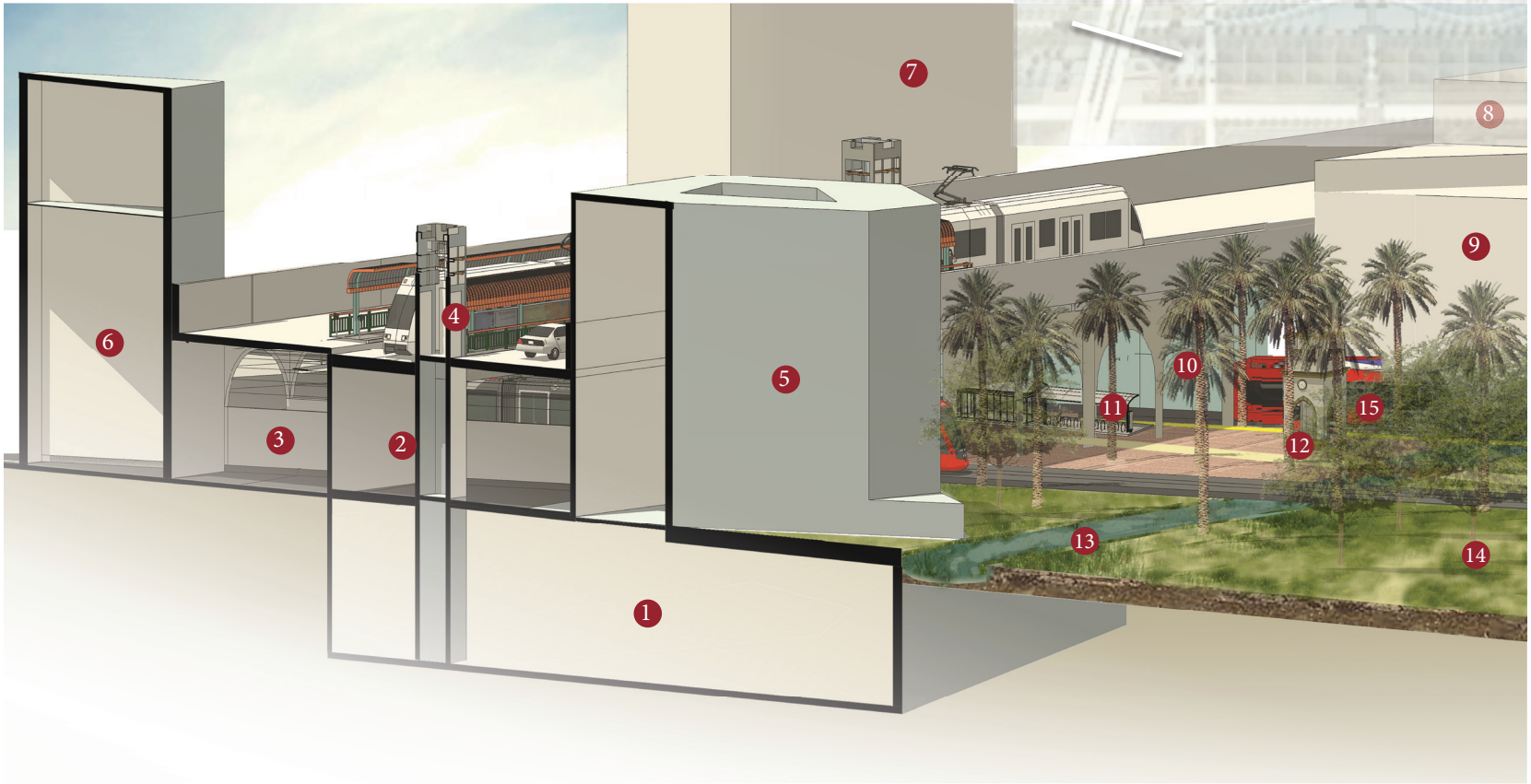
Key

1-LRT station
2-Streetcar station
3-Bus Station
4-Plaza
5-Sadara Headquarter
6-Sabic Headquarter
7-Saudi Aramco Headquarter
8-Chevron Philips Headquarter
9-Sipchem Headquarter
10-Schlumberger Headquarter
11-Mosqiue
12-Industrial Mall
13-Industrial Gift Shop+Mart
14-Museum of Industry
15-Solar Panels Farm
16-Streetcar Stop
17-Bus Stop
18-Detintion Basin
19-Detintion Basin
20-Service Building
21-Seawater Cooling Canal
22-Green Street
23-Sport Yard
24-Industrial Infrastructure



INDUSTRIAL HUB SECTIONS

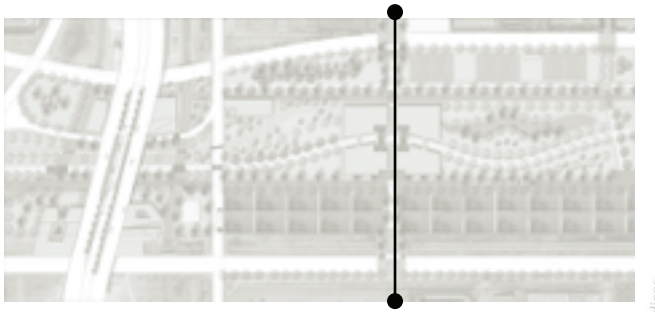
Section Perspective demonstrate the interaction between the hub and mobility

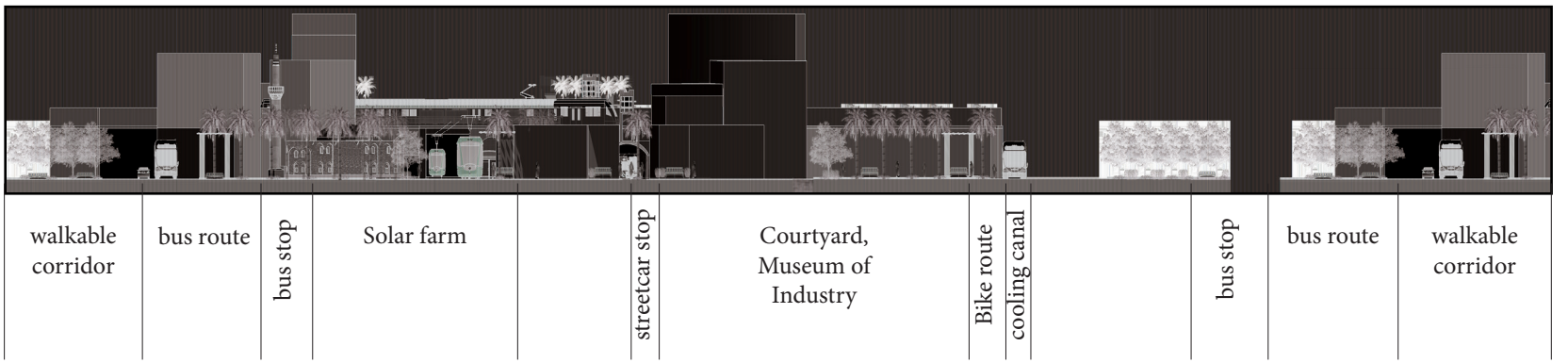


1. Parking Garage
2. Streetcar Station
3. Industry Mall
4. Cooling tower+Elevator
5. Sadara Headquarter
6. Saudi Aramco Headquarter
7. Chevron Philips Headquarter
8. Sipchem Headquarter
9. Schlumberger Headquarter
10. Bus Station
11. Bike Rental
12. Main Plaza
13. Seawater Cooling Canal
14. Lawn
15. Sabic Fountain Sculpture

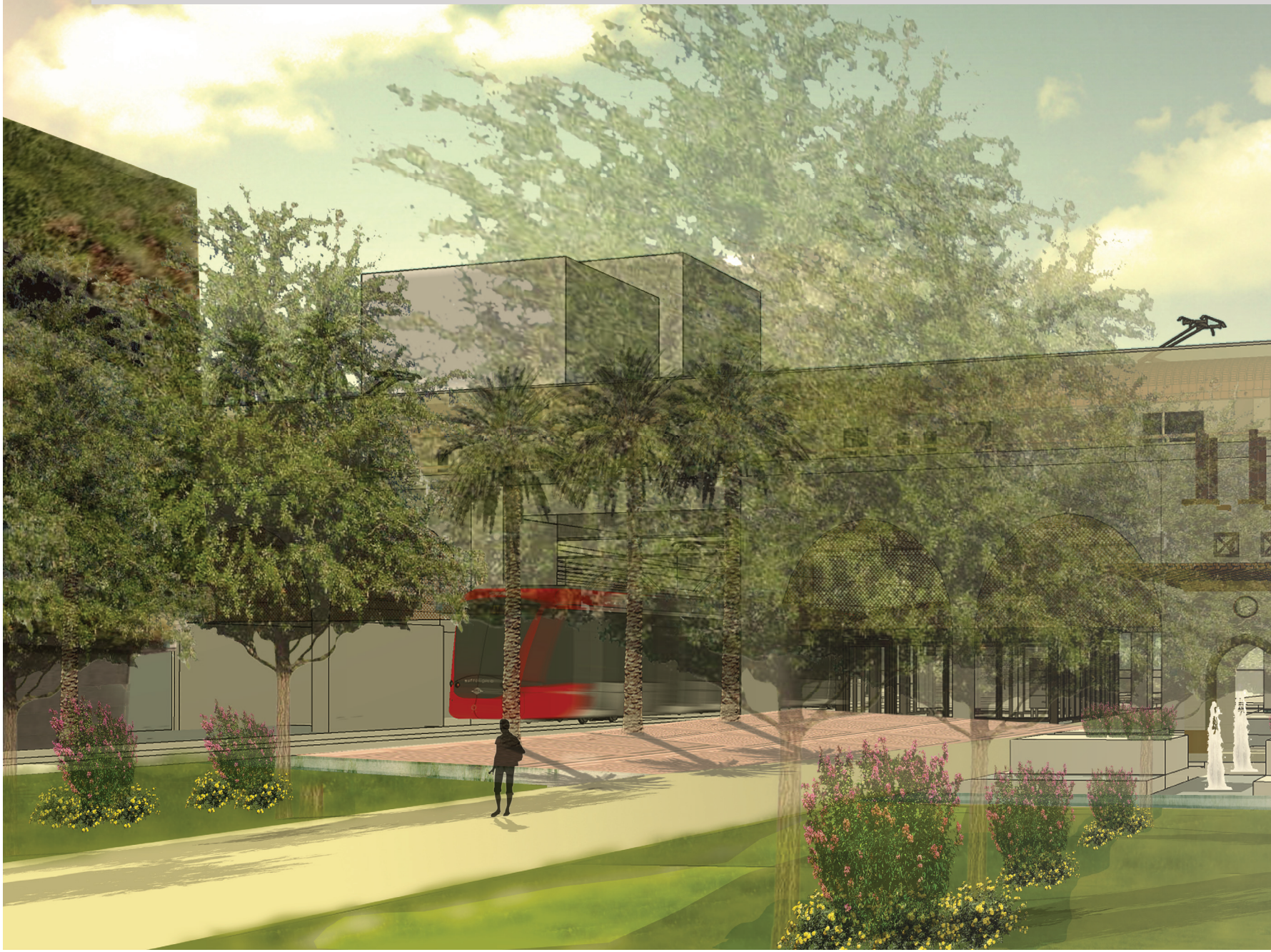
5m 15m 30m 45m

Long section shows the connectivity between industrial and residential area among the linear park





INDUSTRIAL HUB PERSPECTIVES

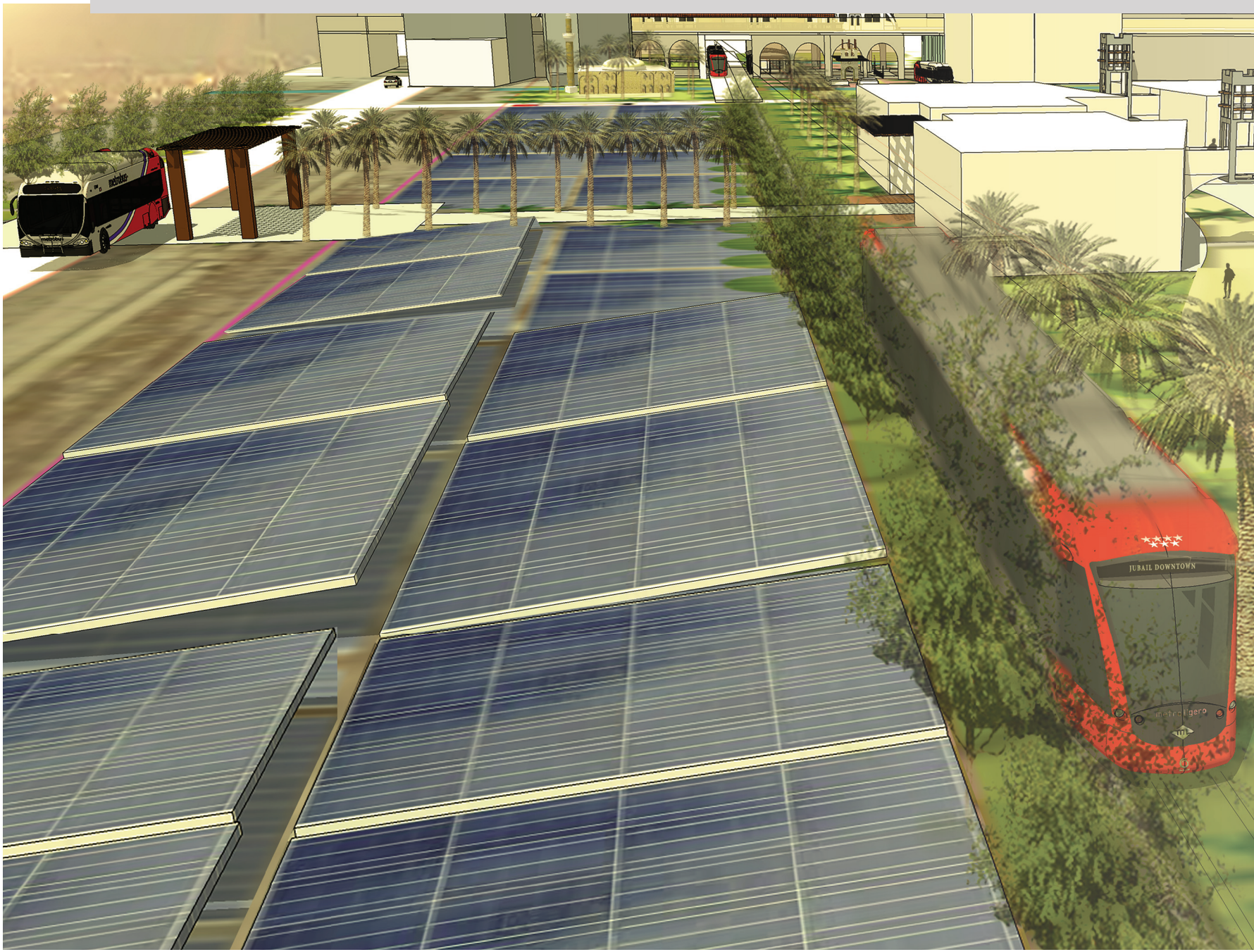


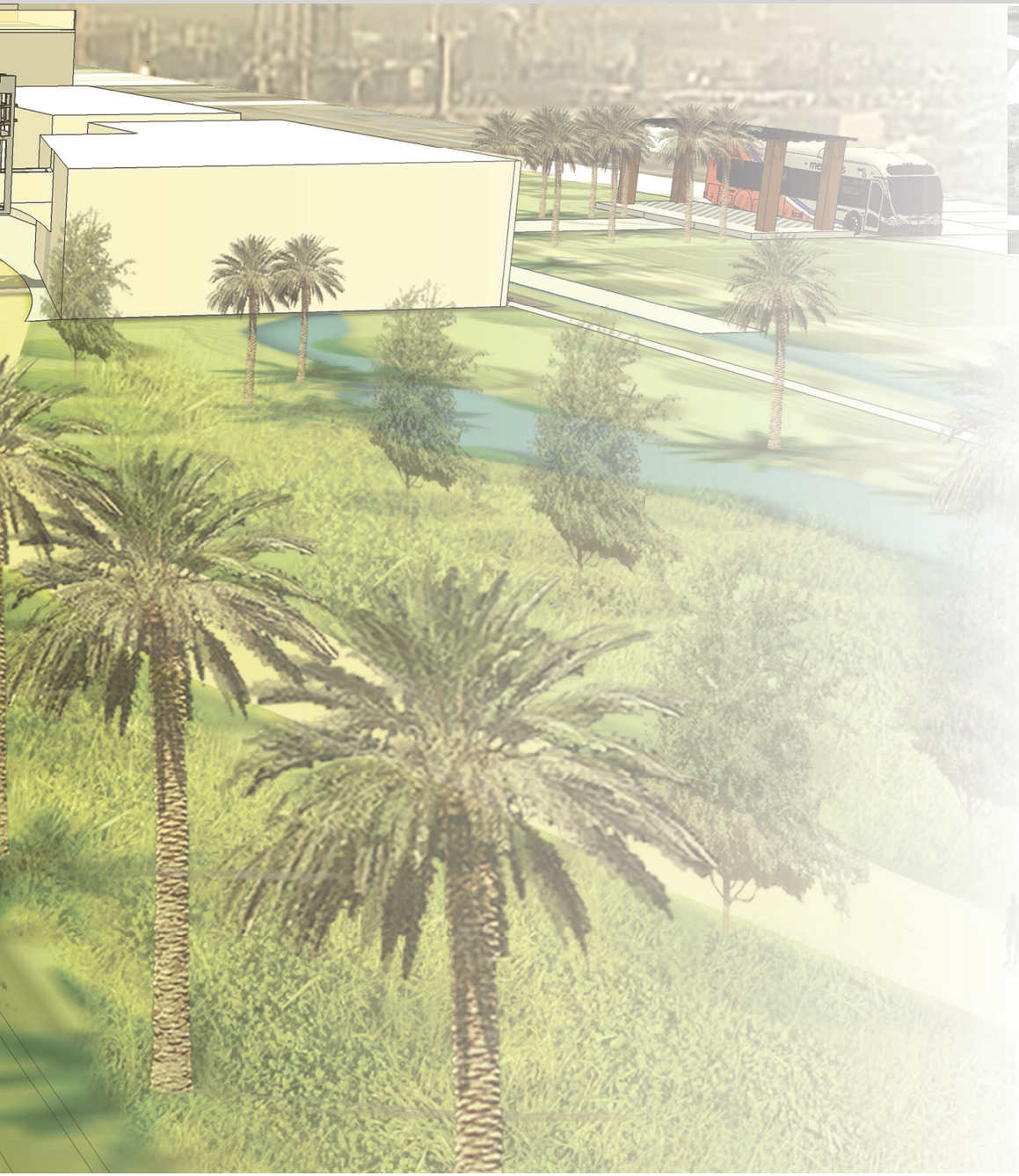
This perspective looking toward the industrial hub, which demonstrate the walkability, accessibility, and interaction between multi-modal transit light rail, streetcar, bus, car, and bicycle. As this perspective shows the architectural style that used to illustrate the ancient passive cooling techniques such as wind catcher, mashrabia shade and ventilation method, which will mitigate the local hot climate.

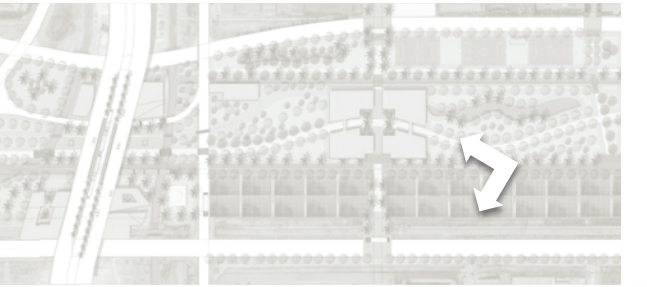
INDUSTRIAL HUB PERSPECTIVES

This perspective demonstrate the interacting between multi-modal transits with the sea water cooling canal. This canal used as a aesthetic and water harvesting uses, which irrigate the linear park and cooling the industrial hub. This canal pass through many treatments to be valuable for plants and public to use. Moreover, this perspective shows how streetcar, pedestrian, bikes, and bus pass over the canal and connected with the linear park by sculpture and fountains located in the gathering area.

INDUSTRIAL HUB PERSPECTIVES

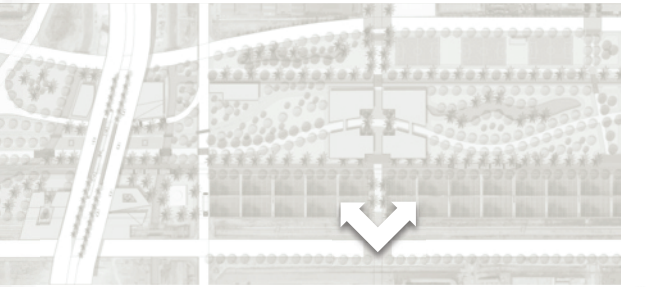






This Aerial view illustrate the connectivity and walkability between the industrial and residential districts among the linear park. Those districts are well connected by transit stops and walkable streets, that will give the employee entertainment amenities withing a walking distance. This pedestrian link is attached by the Museum of Industry, which give the visitor easy access to the industrial districts. Finally, this aerial shows the water harvesting techniques, which provide a man made lake to reduce local heat and irrigate the plants.

INDUSTRIAL HUB PERSPECTIVES



This perspective shows the connectivity between the industrial district and residential district, among the Museum of industry and linear park. As this view shows how the walkways shaded by solar panels to provide shade and generate electricity for the multi-modal transit. This path enhance walkability and lead the employee and residents to the Museum by provide bus, and streetcar stops, bike path, and shaded walkway. The courtyard is significant area, covered by solar panels and provides amenities for employees.

CONCLUSION

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In conclusion, this report provided some suggestions and strategies for multi-modal transportation hubs, which will be a significant trends of transportation in Saudi Arabia. Most employee issues will be solved such as lack of public transportation, congestions, accidents, and pollution. Moreover, multi-modal transit hubs will enhance connectivity, walkability, and increase the income of the Eastern Province of Saudi Arabia, which will attract many international companies to establish a future business.

Multi-modal transportation hubs will connect many factors that will mitigate problems on Dammam Jubail highway such as socio-cultural, economical, and environmental.

FUTURE RECOMMENDATIONS:

1) Provide a detailed GIS model that analyze density, wildlife, vegetation, demographic, circulation, existing condition, and future smart growth.

2) Analyze the contexts for each hub and design appropriate connectivity and walkability that reflect the theme of the neighborhood.

3) Connect the Saudi Railway Organization plan with multi-modal transportation hubs strategies, to provide opportunities for renewable energy use and enhancing walkability and connectivity between Gulf Council Countries and the Eastern Province of Saudi Arabia.

REFERENCES

1. Gulf Encyclopedia for Sustainable Urbanism. (2012)
2. Rcjy.gov.sa, (2014). Royal Commission for Jubail and Yanbu Internet Site. [online] Available at: http://www.rcjy.gov.sa/en-US/Pages/default.aspx
3. Saudirailways.org, (2014). Saudi Railways Organization. [online] Available at: http://www.saudirailways.org/portal/page/portal/PRTS/root
4. Brown, R. (2010). Design with microclimate. 1st ed. Washington: Island Press.
5. http://www.rcjy.gov.sa/en-US/Jubail/AboutCity/Pages/default.aspx
6. Railways of Saudi Arabia Investing in our Future. (2013)
7. Brown, R., Gillespie, T. and Guy, S. (1995). Microclimatic landscape design. 1st ed. New York: Wiley.
8. James, G. (2014). Jubail City Planning Conference RIC – JIC Transportation Link Study.
9. http://www.apricum-group.com/hidden-champions-of-the-emerging-wind-markets/
10. Mot.gov.sa, (2014). Saudi's Ministry of Transport. [online] Available at: https://www.mot.gov.sa [Accessed 12 Oct. 2014].
11. Abu Dhabi Public Realm Design Manual. (2007). 1st ed. Abu Dhabi, UAE: Abu Dhabi Urban Planning Council Abu Dhabi, United Arab Emirates.
12. AICP-Williams, K., Seggerman, K. and Nikitopoulos, I. (2004). Model regulations and plan amendments for multimodal transportation districts.
13. AICP-Williams, K., Seggerman, K. and Nikitopoulos, I. (2004). Model regulations and plan amendments for multimodal transportation districts.

14. Asla.org,. 2014. 'ASLA 2011 Professional Awards | Portland Mall Revitalization'. http://www.asla.org/2011awards/091.html.

15. Clarke, Pelli. 2014. http://www.designboom.com/architecture/transbay-transit-center-transforms-san-francisco-by-pelli-clarke-pelli/#sthash.1p7ZKDpZ.dpuf.

16. Council, Metropolitan. 2014. 'Talking Transit - Friday, January 13, 2012'. Metroplanning.Org. http://www.metroplanning.org/news/newsletters/155.

17. D.A. Hensher and J. King (1996) (eds) Proceedings of the 7th World Conference on

18. Sf-planning.org,. 2014. 'City Design Group: Transit Center District Plan'. http://www.sf-planning.org/ftp/CDG/CDG_transit_center.htm#draft_plan.

19. Shapiro, R., Hassett, K. and Arnold, F. (2002). Conserving energy and preserving the environment: The role of public transportation. American Public Transportation Association, 9.

20. -TOD-Anon, (2014). [online] Available at: http://Multimodal System Design Guidelines Appendix G: Best Practices Research.

21. Transport Research, Sydney: Pergamon.

22. -Yu, J. (2010). Locating urban transit hubs: A multi-criteria model and case study in China.

23. -Zgf.com,. 2014. 'ZGF » Portfolio'. http://www.zgf.com/portfolio/.

24. Moi.gov.sa,. 2014. 'Ministry Of Interior Kingdom Of Saudi Arabia'.http://www.moi.gov.sa/wps/portal/traffic/!ut/p/b1/04_SjzQ0NTOxMDKzNLHUj9CPykssy0xPLMnMz0vMAfGjzO

25.Orbaşli, Aylin, and Simon Woodward. 2008. 'A Railway 'Route' As A Linear Heritage Attraction: The Hijaz Railway In The Kingdom Of Saudi Arabia'. Journal Of Heritage Tourism 3 (3): 159. doi:10.2167/jht021.0.

26. http://www.constructionweekonline.com/article-23915-saudi-aramcos-al-midra-wins-leed-platinum-award/
27. http://riyadh-metro.com
28. http://www.saudirailways.org/portal/page/portal/PRTS/root
29. Orbaşli, Aylin, and Simon Woodward. 2008.
30. http://www.asla.org/2012awards/572.html